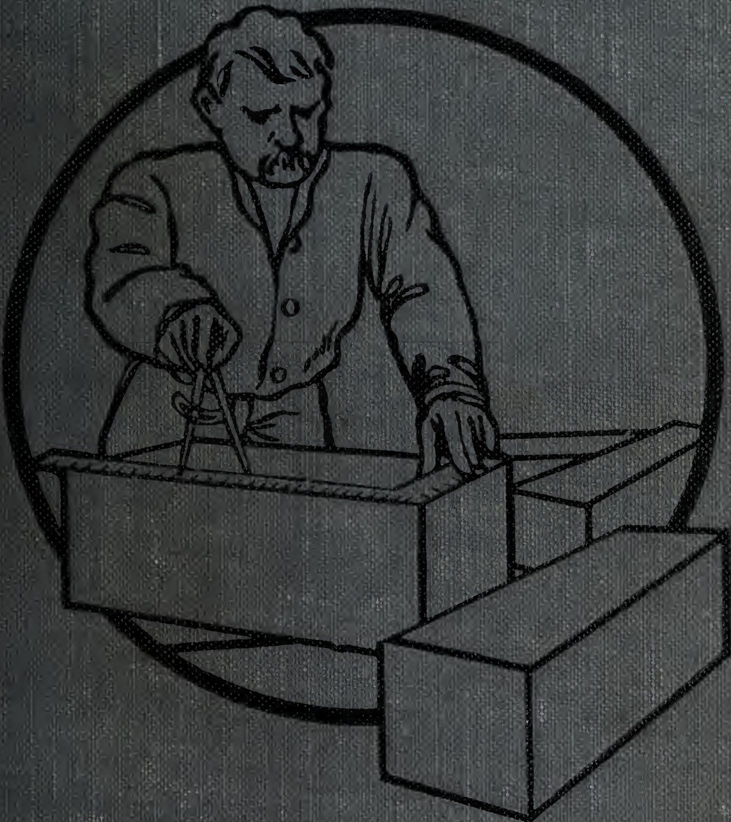
PRACTICAL STONE MASONRY SELF TAUGHT



FOR HOME STUDY

HODGSON

PRACTICAL STONEMASONRY SELF-TAUGHT

ESPECIALLY DESIGNED FOR HOME STUDY

Being a series of practical instructions for the use of stone-masons, stone-cutters, marble-workers and stone contractors; showing how to lay out and work all kinds of arches, stone steps, stairs and hand-rails, skew bridges and arches, circle on circle work, niches, classic and gothic stonework, piers and other stonework, plain and ornamental.

By FRED T. HODGSON, Architect

Author of "Steel Square," "Modern Carpentry," "Architectural Drawing," "Modern Estimator," etc., etc.

ILLUSTRATED

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NOTE TO THE READER.

This book was formerly published in two parts, one part being on Bricklaying work, which is the reason for the folios commencing at Page 181. This part has been revised and enlarged and is a complete work in every respect on stonemasonry.

THE PUBLISHERS.

STONEMASONS' GUIDE

MASONS' WORK

INTRODUCTION

A mason, properly speaking, means a builder, which is evident from the connection between the French words maçon, a mason; maison, a house, and maisonner, to build houses; but in America it is customary to look upon a mason and a stone mason as one and the same, a builder in bricks being always called a bricklayer. In Ireland the term masonry is specially applied to stone-walling, as distinguished from the cut stonework used in dressings and other work of a superior description.

In this country masonry is the art of building in stone in a similar manner to that of brick, with the exception that brickwork is carried out with uniform sized blocks, thus admitting of a number of definite systems of laying the bricks; whereas in stone, owing to the expense in working the material, the face stones only are squared, and the interior or hearting is filled up with smaller stones roughly fitted with a hammer. The stones are in the great majority of cases of varying dimensions, thereby making it a matter of great skill to obtain a proper bond in the work; and owing to the irregular shape of the material the walls have to be made considerably thicker than walls of the same height in brick, with the exception where the walls are built of coursed stones properly squared, in which

case the thickness may be even less than that of brick walls.

The great dimensions in which stone may be obtained, lends itself to a much greater degree than bricks for buildings of architectural pretensions, rendering it possible to have cornices and corbelled work of great projection, which is impossible in brickwork.

TECHNICAL TERMS

The following is a list, and also an explanation, of some terms used in stonework:

Bond, Lap, and Course.—These terms have the same meaning as given under brickwork.

Through Stones.—Stones which extend through the entire thickness of walls to tie or bond them. These are objectionable, as damp is more likely to show on the interior of walls where the continuity of the material is uninterrupted.

Headers.—The name applied to stones, the lengths of which are ⅔ to ¾ thickness of the wall, laid transversely.

Bonders.—These may be either "throughs" or "headers."

Grout.—This is a thin mortar, which is poured over the stones when brought up to a level surface, to fill up any interstices between the stones in the hearting of walls or other positions as necessity requires.

Spalls or Shivers.—These are broken chips of stone, worked off in the dressing.

Weathering.—The top face of a stone worked to a plane surface inclined to the horizontal for the purpose of throwing off the water is said to be weathered, as in sills, cornices, etc.

Footings.—The object of footings is the same as in brick walls. Stone footings should be large, rectangular, through stone blocks. Square stones in plan are not so good as oblong. All stones in the same course must be of the same height, but all courses need not necessarily be of the same depth. The breadth of set-offs need not exceed 3 or 4 in.

If the expense of stone is an objection, footings may be made of bricks or beds of concrete of sufficient depth. See chapters on Foundation and on Brickwork.

Bed Surface.—The bed surface must be worked in one plane surface. Masons, to form thin joints, often make the beds hollow. This is bad, as it is liable to spall; all the pressure will be thrown on the outer part, which is liable to spall the edge of the stone.

Galleting.—The term given when small pebbles are pressed into the face joints of rubble walls to preserve the mortar and to give a pleasing effect.

Dressings.—Stones are said to be dressed when their faces are brought to a fair surface; but cut or prepared stones used as finishings to quoins, window and door openings, are described as dressings.

Quoins.—In rubble and inferior stone walls, quoins are built of good blocks of ashlar stone to give strength to the wall. These are sometimes worked to give a pleasing effect, and where hammer dressed and chamfered are said to be rusticated. They are, at times, merely built with a rough or quarry face, only having the four face edges of each stone lying in one plane.

Window and Door Jambs.—For purposes of strength these should be of cut stone, attention being given that each course is securely bonded. For that reason

it would not be advisable to build them of rubble.

Stoncheons.—The stones forming the inside angle of the jamb of a door or window opening. These are often cast in concrete to effect a saving in labor.

Sills.—These are the lower horizontal members of openings; those in stone are usually of one length, being pinned in cement to both sides of the opening. They should be fixed after the carcass of a building has been finished, and any settlement that was likely to occur through a number of wet mortar joints has taken place. They may be plain and square, as for door sills, or sunk, weathered, moulded with drip and with properly formed stools, and grooved for metal water bar, or moulded, grooved and weathered.

Corbel.—A stone projecting from a wall to support a projecting feature.

Skew Corbel.—Is a projecting stone at the lowest part of the triangular portion of the gable end of a wall supporting the starting piece of coping, and resisting the sliding tendency of the latter. The skew corbels are often tied into the wall by long iron cramps.

Kneeler or Skewput.—This is a long stone, tailing well into the gable wall, and resists the sliding tendency of the coping.

Saddle or Apex Stone.—The highest stone of a gable end, cut to form the termination of two adjacent inclined surfaces.

Lacing Course.—Owing to the absence of bond in some walls, courses of bricks, three deep, are inserted at intervals, to give strength to the wall and bring it to a level surface. Sometimes the name is applied to a horizontal band of stone placed in rubble or rough walls to form a longitudinal tie.

String Courses.—Horizontal bands of stone sometimes moulded and projecting, often carried below windows to accentuate the horizontal divisions of a building.

Plinth.—A horizontal projecting course or courses built at the base of a wall. These are to protect the wall, and are often built in hard hammer-dressed stones.

Cornices.—The moulded course of masonry crowning buildings, generally having a large projection to throw off the rain.

Saddled or Water Joint.—To protect the joints of cornices and other exposed horizontal surfaces of masonry, the sinking is sometimes stopped before the joint and weathered off. Any water passing down the weathered surface is guided away from the joint. The expense of this joint often prohibits its use.

Blocking Course.—A course of stones erected to make a termination to the cornice, the object being to gain extra weight to tail down the cornice, and to form a parapet.

Coping.—The highest and covering course of masonry, forming a waterproof top, to preserve the interior of wall from wet, which in frosty weather might burst the wall. Fig. 52, B. shows a coping flat on the top surface, which should be used only for inclined surfaces, as on a gable, or in sheltered positions. Saddle-back is the name applied when the upper surface is weathered both ways; and segmental, when the section of copings shows the upper surface to be a part of a circle.

Rebated Joints.—These joints are used for stone roofs and copings to obtain weather-tight joints. There are two kinds: 1, when both stones are rebated; 2, when the upper stone only is rebated. In the first case the stones are of the same thickness throughout,

their upper surface being level when the joint is made. In the second case the stones are thicker at the bottom edges than at the top, the bottom edge having a rebate taken out equal to the thickness of the upper edge of the stone below it, over which it fits. The part that laps over should not be less than ¾ in. thick. The upper surfaces or beds of the stones should be level.

Throatings.—Grooves on the under surfaces of copings, sills, string courses, etc., acting as drips for any water that would otherwise trickle down and disfigure the walls.

Templates.—Slabs of stone placed under the end of a beam or girder to distribute the weight over a greater area.

Gable Details.—The tops of stone walls are protected by coping, and these, where placed on steep gables, need support at their lower ends and at intervals; this may be done by constructing a shoulder at the foot, or by the use of skew corbels. The intermediate supports are obtained by kneelers, which consist of stones having a part worked as a coping, the remainder tailing well into the wall.

Corbie Step Gables.—A common method of finishing gables is by constructing a number of steps formed of some hard stone squared, the top surfaces being slightly weathered and known as corbie or crow-step gabling.

Gablets.—Many skew corbels are constructed with a small gablet, which gives extra weight to the skew corbel, thus rendering it more efficient for resisting the outward thrust of the coping stones. The apex stones are often treated in a similar manner.

Corbel-table.—A system of corbeling supporting a parapet, often forming an architectural feature.

Finial.—The aspiring ornament of an apex stone often richly foliated.

Parapet.—The fence wall in front of the gutter at the eaves of a roof. The castellated parapet is formed by a number of embrasures similar to the parapets used in ancient military buildings, much used in the later Gothic work as an ornamental feature.

Diaper Work.—Is the name given to bands, surfaces and panels in the stone work formed by square stones and similar squares, filled in with brick or flint work, giving a checkered appearance. The term is also applied to any ornament arranged in squares upon the surface of ashlar masonry.

Tympanum.—The masonry filling in between the relieving arch and the head of a door or window. Advantage is often taken of this to form a ground for carved ornament.

Gargoyle.—Is a stone water-spout, employed in buildings of Gothic character to carry off the rain from the gutters. These project sufficiently far to throw the water clear of the building. At present down pipes are employed, but the gargoyle is often retained as an overflow in lieu of a warning pipe.

Tailing Irons.—These are formed of H, L, or T irons for holding down the ends of corbels in oriel windows.

Lintels.—Wide spans requiring to be bridged by stone lintels (as is the case in the trabeated styles of architecture) are often of a greater dimension than can be conveniently obtained in one stone, in which case the lintel is built up in one of two ways:

(1) By an arched construction. The sloping joints in this method are considered objectionable by some, altering as it does the principle of the construction from the beam to the arch, the number of small pieces

detracting from the general effect. Vertical joints are preferred to inclined. The arched principle, with vertical jointed voussoirs, may be carried out by forming the joint vertically on and about 4 in. below the face and the remainder to the back, or, if seen on both sides, in the center of the lintel. The stone cut thus form voussoirs of an inch.

(2) The method now most usually adopted is to build the lintel up of a number of pieces with vertical joints and in two thicknesses, the front and back portion being made to envelop the flanges of a steel girder, which bridges the whole span and takes its bearing on the columns. The back and front pieces are connected on the soffit, and the upper surface by small copper cramps, the latter being bedded in cement mixed with dust from the stones to be united. The hole soffit is finally rubbed over with a piece of stone similar tó the lintels, to render the joint as nearly as possible invisible. Care must be taken to protect the iron girder from the danger of oxidation by applying one of the preservative processes employed for iron and steel.

The stone entablatures built over shop fronts are formed in this way, but have the stone on one side only of the girder, being connected to the same with cramps.

The masonry above stone lintels should be disposed to throw, as much as possible, the weight of the superimposed walling on to the supports, and not unnecessarily stress the lintel.

Labors.—The following are the chief labors adopted in preparing stone work:

Half-Sawing.—The surface left by the saw; half the cost of the sawing being charged to each part of the separated stone.

Self-faced.—The term applied to the quarry face, or the surface formed when the stone is detached from the mass in the quarry; also the surfaces formed when a stone is split in two.

Scabbling or Scappling.—That is, taking off the irregular angles of stone; is usually done at the quarry, and is then said to be quarry pitched, hammer faced or hammer blocked; when used with such faces the stone is called rock or rustic work.

Hammer Dressing.—Roughest description of work after scabbling.

Chisel Drafted Margin.—To insure good fitting joints in hammer faced stones, a true surface about an inch wide is cut with a chisel, forming a margin on the face of stone.

Plain Work.—This is divided, for purposes of valuation, into half plain and plain work. The former term is used when the surface of the stone has been brought to an approximately true surface, either by the saw or with the chisel. Plain work is the term adopted for surfaces that have been taken accurately out of winding with the chisel. Half plain is usually placed upon the bed and side joints of stones in ashlar work and plain work on the face.

Rubbed Work.—This labor consists in rubbing the surfaces of stones until perfectly regular, and as smooth as possible. The work is accomplished by rubbing a piece of stone with a second piece. During the first stages of the process, water and sand are added, gradually reducing the quantity of sand up to the finish. Large quantities of stones are rubbed by means of large revolving iron discs, on which the stones are placed, and kept from revolving with the disc by means of stationary timbers fixed a few inches

above and across the table. Water and sand are added to accelerate the process. Only plane surfaces can be rubbed in this way.

Polishing.—Marbles, after the rubbed operation, are brought to a still smoother surface by being well rubbed with flannel and a paste of beeswax and turpentine or putty. The polishing of granite has been described elsewhere.

Boasted or Droved Work.—This consists in making a number of parallel chisel marks across the surface of the stone by means of a chisel termed a boaster, which has an edge about 2½ in. in width. In this labor, the chisel marks are not kept in continuous rows across the whole width of the stone.

Tooled Work.—This labor is a superior form of the above, care being taken to keep the chisel marks in continuous lines across the width of the stone. The object of this and the preceding is to increase the effect of large plane surfaces by adding a number of shadows and high lights. This labor is sometimes known as scabbled work.

Axed Work.—Axed work and tooled work are similar labors. The axe is employed for hard stones, such as granite, but the mallet and chisel for soft stones, being more expeditious.

The method of preparing the hard stones after being detached from their beds in the quarry is as follows: The stones are roughly squared with the spall hammer; the beds are then prepared by sinking a chisel draught about the four edges of the bed under operation, the opposite draughts being out of winding, and the four draughts in the same plane surface; the portions projecting beyond the draught are then taken off with the pick. After the pick the surface is wrought with the

axe, the latter being worked vertically downward upon the surface, and taken from one side of the stone to the other, and making a number of parallel incisions or bats; the axe is worked in successive rows across the stone, the incisions made being kept continuous across the surface. In axed work there are about four incisions to the inch. This labor is used for the beds of stones for thresholds and curbstones, and in this state the pick marks are easily discernible. Fine axed work is a finer description of axed work, and is accomplished with a much lighter axe having a finer edge. In fine axed work there would be eight incisions to the inch.

Furrowed Work.—This labor, used to accentuate quoins, consists in sinking a draught about the four sides of the face of a stone, leaving the central portion projecting about ⅜ of an inch, in which a number of vertical grooves about ⅜ in. wide are sunk.

Combed or Dragged Work.—This is a labor employed to work off all irregularities on the surfaces of soft stones. The drag or comb is the implement used. It consists of a piece of steel with a number of teeth like those of a saw. This is drawn over the surface of the stone in all directions, making it approximately smooth.

Vermiculated Work.—This labor is placed chiefly on quoin stones to give effect. The process is as follows: A margin of about ¾ in. is marked about the edge of the stone, and in the surface enclosed by the margin a number of irregularly shaped sinkings are made. The latter have a margin of a constant width of about ⅜ in. between them. The sinkings are made about ¼ in. in depth. The sunk surface is punched with a pointed tool to give it a rough pockmarked appearance.

Pointed Work.—The bed and side joint of stones are

often worked up to an approximately true surface by means of a pointed tool or punch. This labor is often employed to give a bold appearance to quoin and plinth stones, and where so used it usually has a chisel-draughted margin about the perimeter.

Moulded Work.—Mouldings of various profiles arc worked upon stones for ornamental effect. Mouldings are worked by hand as well as by machine. In the former case, the profile of the moulding is marked on the two ends of the stone to be treated by means of a point drawn about the edge of a zinc mould, cut to the shape of the profile. A draught is then sunk in the two ends to the shape of the required profile. The superfluous stuff is then cut away with the chisel, the surface between the two draughts being tested for accuracy by means of straight-edges. The machines for moulded work somewhat resemble the planing machjnes for metal work. The stone is fixed to a moving table. The latter has imparted to it a reciprocating rectilinear motion, pressing against a fixed cutter of the shape of required profile, or some member of it. The cutter is moved near to the stone after each journey, thus gradually removing the superfluous stuff till the profile is completed. Moulded work is, strictly speaking, the name given to profiles formed with a change of curvature, and therefore should not be applied to cylindrical sections, such as columns.

The weathering properties of stones moulded by hand labor are considered by some far superior to those worked by machinery, as in the latter method the moulding irons, being driven continuously, become heated and partially calcine the surfaces of the stones, thus rendering it peculiarly susceptible to atmospheric deterioration.

Moulded Work Circular.—This term is given to mouldings stuck upon circular or curved surfaces in plan or elevation.

Sunk Work.—This term is applied to the labor of making any surface below that originally formed, such as chamfers, wide grooves, the sloping surfaces of sills, etc. If the surface is rough, it is known as half-sunk; if smooth, sunk, and any other labor applied must be added, such as sunk, rubbed, etc.

Circular Work.—Labor put upon the surface of any convex prismatic body, such as the parallel shaft of a column or large moulding, is termed circular work.

Circular Sunk Work.—Labor put upon the surface of any concave prismatic body, such as a large hollow moulding, or the soffit of an arch, is termed circular sunk work.

Circular Circular Work.—The labor placed upon columns with entases, spherical or domical work.

Circular Circular Sunk.—The labor worked upon the interior concave surfaces of domes, etc.

Internal Miters.—The name given to the intersections of two mouldings making an angle less than 180 degrees.

External Miters.—The name given to the intersection of two mouldings making an angle greater than 180 degrees.

Returned Mitered and Stopped.—The name given to a moulding returned in itself, and stopping against an intersecting surface.

Long and Short Work.—This work is often used for quoins and dressings in rubble walls, and is especially noticeable in old Saxon work. It consists in placing alternately a flat slab, which serves as a bonder, and a long stone approximately small and square in section.

This arrangement in modern work is sometimes known as block and start work.

Stone Walling.—Is divided under the following headings: 1, Rubble; 2, Block in Course; 3, Ashlar. Illustrations of these various kinds of walling will be shown later on.

Rubble walls are those built of thinly bedded stone, generally under 9 in. in depth, of irregular shapes as in random rubble or squared as in coursed rubble.

Block in course is composed of squared stones usually larger than coursed rubble, and under 12 in. in depth.

Ashlar is the name given to stones, from 12 to 18 in. deep, dressed with a scabbling hammer, or sawed to blocks of given dimensions and carefully worked to obtain fine joints.

The length of a soft stone for resisting pressure should not exceed three times its depth; the breadth from one-and-a-half to twice its depth; the length in harder stones four to five times its depth, and breadth three times its depth.

Random Rubble.—The name given to walling built of stones that are not squared, but roughly fitted with a waller's hammer.

Random Rubble Set Dry.—In the stone districts boundary walls are built of rubble set without mortar. The top is built of heavy stones, which are usually bedded in earth, to prevent slight movement.

Uncoursed Random Rubble Set in Mortar.—In these the stones are used as they come from the quarry, care being taken to obtain them as uniform as possible, and roughly fitting with the waller's hammer; one bond stone is used in every super yard on face; any openings between stones to be pinned in with spalls. If

good mortar is used, walls built of random rubble should be made one-third thicker than the thickness necessary for brick walls.

Random Rubble Built in Courses.—This consists of stones forming horizontal beds at intervals of 12 to 18 in., every stone being bedded in mortar. The object of coursing is to insure that there shall be no continuous vertical joints. To save expense in bedding each stone in mortar, masons bed only the stones on faces of wall, and at these levels pour a pail of thin mortar, called grout, to fill up any cross joints between stones, taking care that the hearting stones are properly interlocked.

Uncoursed Squared or Snecked Rubble.—Stones roughly squared and hammer or axe faced, the vertical depth of the stones usually being less than 9 in; to prevent continuous long horizontal joints, small stones, termed snecks, are placed at intervals adjacent to a large stone, the beds of both being level and thereby commencing a horizontal joint at another level.

Squared Rubble Built in Courses.—Squared rubble is brought up to level beds with dressed quoins. The coursing is to prevent continuous vertical joints. It is sometimes known as irregular coursed rubble, as the courses need not all be of a uniform depth.

Regular Coursed Rubble.—In this kind of work all stones in one course are squared to the same height, usually varying from 4 in. to 9 in., and are generally obtained from thin but regular beds of stone.

Block in Course is the name applied to stone walling, chiefly used by engineers in embankment walls, harbor walls, etc., where strength and durability are required. The stones are all squared and brought to good fair joints, the faces usually being hammer-dressed. Block

in course closely resembles coursed rubble, or ashlar, according to the quality of the work put upon it.

Ashlar.—Ashlar is the name applied to stones that are carefully worked, and are usually over 12 in. in depth.

As the expense would be too costly to have walls built entirely of ashlar, they are constructed to have ashlar facing and rubble backing, or ashlar facing and brick backing, but, as the backing would have a greater number of joints than the ashlar, the backing should be built in cement mortar, and brought to a level at every bed joint of the ashlar, to insure equality of settlement.

The ashlar facing may be plain, rebated, or chamfered, and looks best when laid similar to Flemish bond in brickwork.

JOINTS

In arranging the joints of masonry the following general principles should be observed:

1. All the bed joints must be arranged at right angles to the pressure coming upon them.
2. Joints should be arranged to prevent any members, such as sills, being under a cross-stress.
3. The joint should be arranged so as to leave no acute angles on either of the pieces joined.

The first condition applies to all kinds of masonry. It is necessary to prevent any sliding tendency taking place between the stones.

The second condition applies chiefly to sills in window openings. These, if in one piece, and built into the piers at each side of the opening, are often subjected to a cross-stress, owing to the settlement being greater under the piers than beneath the window open-

ings. This danger occurs more frequently in openings in the lowest story, and the effect of it is to break the sill. In brickwork, this defect is remedied by fixing the sill after the whole of the brickwork has been erected and the settlement taken place; but in stonework, and under conditions where the sill must be fixed as the building proceeds, the breaking of the sill may be prevented by having a vertical joint in the line of the face of the reveal.

If there are any heavy mullions down which pressure may be transmitted, the same precaution must be taken with the sill; but if light mullions occur, the sill may be taken continuously through. In such cases no joint in the sill should occur under the mullions.

The third condition applies chiefly to the joints in tracery work, and any exposed joints in any other work. Stone being a granular material, anything approaching an acute angle is liable to weather badly; therefore in any tracery work having several bars intersecting, a stone must be arranged, to contain the intersections and a short length of each bar, and the joints should be (*a*) at right angles to the directions of the abutting bars if straight, or (*b*) in the directions of a normal to any adjacent curved bar. This not only prevents any acute angles occurring, as would be the case if the joints were made along the line of intersection of the moulding, but also insures a better finish, as the intersection line can be carved more neatly with the chisel, and is more lasting than would be the case if a mortar joint occurred along the above line. In no case, either in tracery, string courses, or other mouldings, should a joint occur at any miter line.

Joints.—These may be classified as follows:

1. To resist compression, such as the square **joint,**

the surface of which is arranged normal to the pressure.

2. To resist tension, cramps, lead plugs and bolts.

3. To resist sliding or displacement, joggle, joints, tabling dowels and pebbles.

Joints to Resist Compression.—Joints in stone under a compressional stress have plane abutting surfaces normal to the stress

Joints to Resist Tension.—The texture of stone is unsuited to form tensional connections. Where there is any tensional stress the joints are best held together by metal connections.

Cramps.—Metal cramps are used to bind work together, and are particularly adapted for positions in which there is a tendency for the stones to come apart, such as in copings covering a gable, or in face stones of no great depth, or cornices and projecting string courses to tie them to the body of the wall. The cramps are made from thin pieces of metal of varying lengths and sectional area according to the work, turned down about 1½ in. at each end. The ends are made rough and inserted into dovetailed-shaped mortises, and the body in a chase made to receive them in the stones to be connected. The cramps are usually prepared from either wrought iron, copper, or bronze. If wrought iron is used, it is usually subjected to some preservative process, such as tarring and sanding or galvanizing, to prevent oxidation. Iron is useful on account of its great tensile strength. Copper is valued for its non-corrosive properties under ordinary conditions, and its tensile strength, which is not much less than wrought iron; it is, however, comparatively soft. Bronze possesses all the properties of copper necessary for cramps, and in addition is much harder, and therefore better.

The best bedding materials are Portland cement, sulphur and sand, asphalt and lead. Care should be taken to completely envelop the cramp in the bedding materials. Stones are also connected by slate cramps set in cement.

Lead Plugs.—Stones may be connected together by means of lead in the following manner: Dovetailed-shaped mortices are made to correspond in the side joints of two adjacent stones, into which, when placed in position, molten lead is poured, and when cool is caulked, thus completely filling the mortises and connecting the pieces.

Bolts.—Stone pinnacles, finials, and similar members, where built of several stones, are usually connected together with iron bolts passing through all of them and binding down to some more stable portion of the work. Cornices with a great projection are secured by long iron bolts, termed anchor bolts, carried well down into the body of the work, and at their lower ends passing through large iron plates termed anchor plates.

Rag Bolts.—Are employed to secure ironwork to stone. The ends of the bolts are often fixed by having the end that is let into the stone jagged, and run with lead, or sulphur and sand, the mortise being dovetailed-shaped to secure it from any upward pressure.

Where there is any probability of a great upward stress a hole is drilled right through the stone and a bolt supplied with a washer passed through in the ordinary manner.

Joints to Resist Sliding.—The following are those most used:

Joggles.—A joggle is a form of joint in which a portion of the side joint of one stone is cut to form a projection, and a corresponding sinking is made in

the side of the adjacent stone for the reception of the projection. It is chiefly used in landings to prevent any movement between the stones joined and so retain a level surface between them, and also to assist in distributing any weight over every stone in the landing.

Tabling Joints.—This is a form of joint that has been used to prevent lateral motion in the stones of a wall subjected to lateral pressure, such as in a sea-wall. It consists of a joggle joint in the bed joints, the projection in this case being about 1½ in. in depth and a third of the breadth of the stone in width. This kind of joint is rarely used now, owing to the great expense in forming it, it being superseded for sea-walls by huge blocks of concrete cast on or near the spot, of a weight sufficient to resist any pressure likely to be brought to bear on them, and usually under other conditions by long slate joggles placed in a space to receive them in the bed joint at the junction of side joints of two stones and the top bed joint of another.

Cement Joggles.—These are generally used in the side joints of the top courses of masonry to prevent lateral movement in them, and consist of a V-shaped sinking in the side joint of each adjacent stone in the same course.

Dowels.—Doweling is another method of obtaining the same result as joggling or tabling. The dowels consist usually of pieces of hard stone or slate about 1 in. square in section, and varying from about 2 in. to 5 in. in length, slightly tapering from the center towards the two ends, being sunk and set in cement in corresponding mortises in the adjacent stones. They are used in both the side and bed joints. They are generally employed in the top courses of masonry

where the weight on or of the individual stones is not great. The united mass thus formed from the collected stones renders any movement impossible under normal conditions.

Pebbles.—Small pebbles, owing to the ease with which they may be fitted, were formerly employed in the joints of stones to prevent sliding. They are now in most work displaced by slate dowels or joggles. The pebbles are still sometimes used for small work.

TOOLS AND APPLIANCES USED IN CUTTING AND BUILDING STONEWORK

The tools used by the mason are many and varied, as different tools are required for different styles of work, and even where the same style of work is being wrought, but being made of softer or harder materials, other sets of tools will be required. Marble and the softer stones are worked with tools that are very much different from those used in working granite or the harder stones.

The following tools and appliances are those mostly used at the present time by operative masons:

Fig. 1. The square is of various sizes, and generally made of steel plate about one-eighth of an inch thick; the edges are parallel and at right angles to each other.

It is important that the square should be true, as the accuracy of the work depends entirely upon it, and for this reason it should be frequently tested for correctness.

Fig. 2. The set square is of several sizes, and made of iron, brass, or zinc plate; it contains a right angle

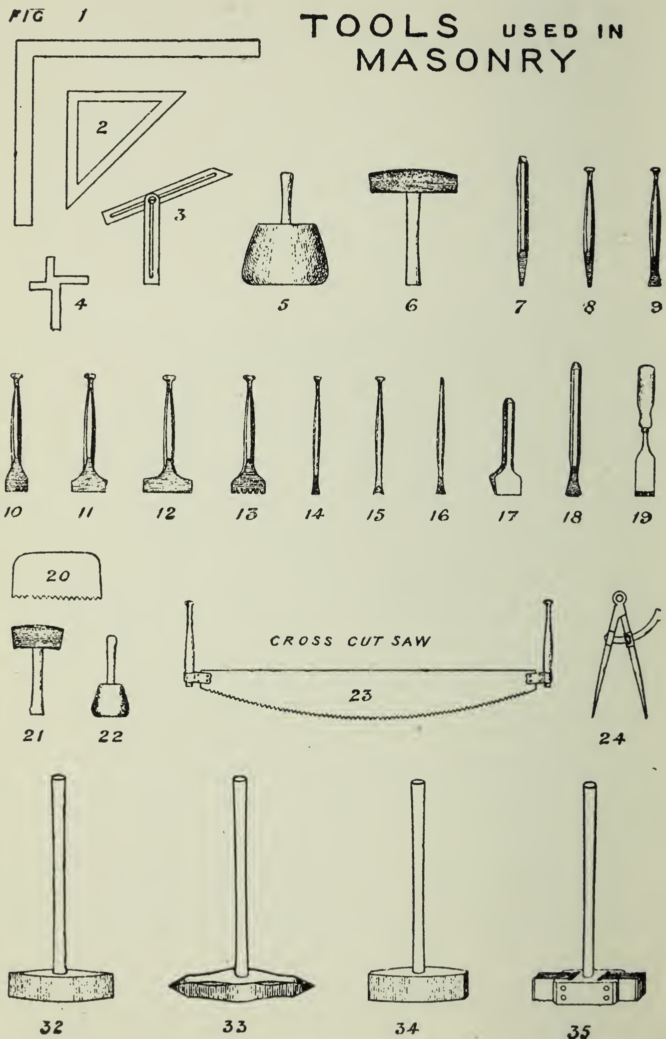
FIG 1
TOOLS USED IN MASONRY
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CROSS CUT SAW
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and two angles of forty-five degrees, and is used chiefly for miters, and setting out on bed of work.

Fig. 3. The bevel, or shift stock, made of iron or brass, and used for sinkings, bevels, etc.

Fig. 4. A small tee square of unequal sides, and with right angles, used for sinkings, etc.

Fig. 5. Mallet of beech, or other hard wood, of various sizes, for striking the cutting tools.

Fig. 6. Hand hammer of steel, about five pounds in weight, used principally with punch for removing waste, and in very hard-grit stones. It is used also with hammer-headed chisels.

Fig. 7. The punch; the cutting edge of this tool is about a quarter of an inch wide, and chisel-pointed. It is used with the hammer for removing all superfluous waste.

Fig. 8. The point, with edge similar to punch, is used with mallet, generally for hard-grit or lime stones, and for reducing the irregularities left from punch, leaving the stone in narrow ridges and furrows close down to face.

Fig. 9. Chisels, of various widths, from ¼ in. to 1½ in. wide, used for mouldings, fillets, sinkings, etc.

Figs. 10 and 11. Boasters, from 1½ in. to 3 in. wide, used for dressing stones down to smooth faces, and cleaning or finishing mouldings, etc.

Fig. 12. Broad-tool, about 4 in. wide, used for tooling.

Fig. 13. Claw-tool. These are of various sizes, the teeth being cut coarse or fine to suit the texture of the stone. For hard lime stones the teeth at point are about ⅛ in. wide, and for softer stones from ¼ to ⅜ in. wide. The claw tool is used after the punch or point, dressing down the ridges still closer to finished face.

Figs. 14 and 15. Small chisels, of various sizes, for carving, letter-cutting, etc.

Fig. 16. Small chisels, called "splitters," of various sizes; the heads are concave, or cup-headed, as in sketch, Fig. 38. When used with an iron hammer, Fig. 21, they cut very smooth and sweet.

They are used mostly for marble work, carving, lettering, etc.

Fig. 17. Pitching tool; this has a beveled instead of a cutting edge, and is used with the hammer, for pitching or knocking off the irregularities or waste lumps on stone.

Fig. 18. Jumper, chisel-pointed and slightly round-nosed; it is wider at cutting edge than the diameter of tool, so that it clears itself in cutting circular holes, for which it is used, chiefly in granite.

Fig. 19. Chisel for soft stone (this is a general term, and comprises varieties like marble or alabaster). The chisels have wood handles, and are similar to carpenters' "firmer chisels."

Fig. 20. Drags for soft stone, of best steel saw-plate, with coarse, middling, and fine teeth, called coarse, seconds, and fine drags. These are used by traversing the face of the stone in all directions and removing the saw and chisel marks, and finishing to any degree of smoothness required.

Fig. 21. Iron hammer, about three or four pounds weight, used with cup headed tools, for carving, lettering, etc.

Fig. 22. Dummy, of lead or zinc, about three or four pounds in weight, used for striking the soft stone

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NOTE—Numbers 8 and 15 are mallet headed tools, and must never be struck with the hammer, the heads being made to receive the blow of the mallet only.

tools; it is handier than the mallet, and at times more convenient to use.

Fig. 23. Cross-cut saw, of best steel plate, and of various sizes, for cutting soft stone blocks, scantling, etc.; the teeth are coarse, and broadly set for clearance. Two men are required in using it.

Fig. 24. Compasses, for setting-out work, etc.

Fig. 25. Shows sketch of a saw frame, for hand-sawing, which in practice requires some little skill in framing up to the various sizes.

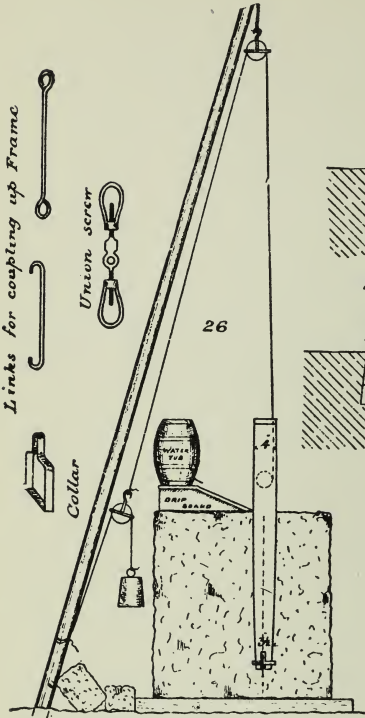
The frame generally, for good working, should be about two feet longer inside than the length of stone to be sawed, so as to allow for draft.

The heads or ends of frame are made of 4×3 in. pine, tapered from near the top to $3\frac{1}{2} \times 2$ in. at the bottom, with a groove or slot for the saw 4 in. deep by $1\frac{1}{4}$ in. wide, the angles being rounded off or smoothed to make it easy for the hands.

The stretcher is a piece of pole about 3 in. in diameter, with iron ferrule at each end, varying in length. Packing pieces are used against the head at each end of stretcher as shown.

The couplings are in wrought iron, $\frac{1}{4}$ in. in diameter, of various lengths and shapes, as in sketch. These are tightened up with a union screw in the center, which keeps the saw taut, so that no difficulty is experienced in getting the saw frame to the required length.

The saw plate is of iron, about 4 in. wide by $\frac{1}{10}$ in. thick, with two holes punched through it, $\frac{3}{4}$ in. in diameter, at each end, for iron pins, which are inserted to keep the saw in position. The pins are 4 in. long, and have a small slot the thickness of the saw plate and $\frac{1}{8}$ in. deep, fixed with the groove towards the end



END VIEW OF SAW

FIG 28

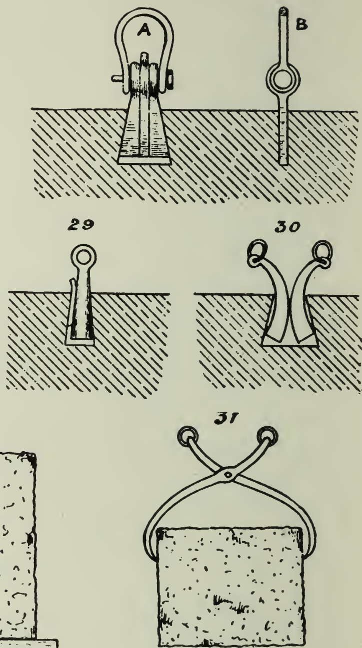
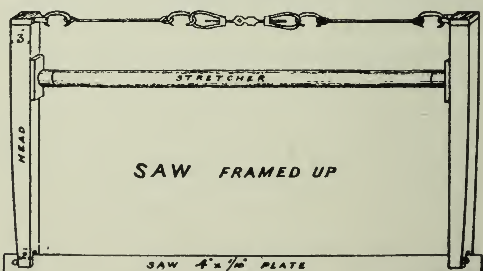


FIG 25



of the saw; this enables the sawyer to keep the saw straight down the cut, by tapping either end of the pin, should the saw deviate from the vertical line. This slot in the pins is important, as the saw cannot be kept true without this arrangement. The pole, for carrying the saw frame, is from 16 to 20 ft. long and 3 or 4 in. diameter at bottom, and tapering towards the top; a crosspiece and chain is secured nearly at the top of pole to carry the pulley. The pole is kept in position by planting it in the ground, and a rough piece or two of stone is laid against it. The cords for carrying the saw frame are about ½ in. in diameter; small chains are sometimes used, but cords work more easily.

The cord is fastened round the stretcher and over the pulleys on top of the pole (which must be vertical to the cut), and then round hook of bottom pulley. The weight must be so adjusted as to allow the saw-frame to be the heavier by about eight or ten pounds; this, however, will depend greatly on the nature of the stone. The position of weight can be raised or lowered to suit the cut by shifting the cord at the bottom of the pole.

The drip board is of pine, as in sketch, and about 2 ft. long, with sloping side against the cut, and on this is placed the water tub; a small spigot is inserted in the bottom of the tub, and is adjusted to allow the water to trickle down the board, carrying with it the sand, which is also on the board, into the cut. To regulate the supply of water and sand, the sawyer uses a small rake with a long handle.

The line of cut for saw should be set out with a plumb rule or bob at each end of the block, and a V-shaped chase cut in to guide the sawyer in keeping to a true line.

The best sand for cutting is hard grit, washed through several sieves, all the coarse and fine being rejected, and the medium size only used. A bushel of this sand will cut about 12 ft. super of stone.

The saw is drawn backwards and forwards and the stone cut by the attrition of the saw plate with the sand and water.

A good sawyer can cut by hand from 15 to 20 ft. super of sandstone in one day of ten hours.

On large jobs steam stone saw frames are used, in which, if necessary, from one to twenty cuts may be put in one block at the same time.

Fig. 27. Shows a method of coping or splitting a block of stone to a required size.

Begin by cutting a V chase on top and two sides of the block, as at *g*, *f*, *e*; directly under this place a wood skid, and on the top of the skid a long iron bar, which should bone with the line *gf*; or a punch driven in on each side, as at *e*, will do nearly as well. At extreme end place a short skid, as at *h*, and packed up to within an inch of the under side of the block. This is done to prevent the coped piece from breaking under by its own weight, as the fracture would not take the line of direction proposed, but would probably break away from *j* to *k* and spoil the block.

Sink wedge holes with the punch (at distances apart varying with the nature of the stone) to as fine a point as possible at the bottom of the hole, as in sketch, at *b*, so that the wedge will bite or hold when struck with the hammer. The apex of the wedge, which is of iron, is blunt pointed and about ¼ in. wide, so that it does not touch the bottom of the hole, or when struck it would jump out. The holes being cut, the wedges are inserted in each one; care must, however, be taken

to keep them upright, so that the cleavage takes the line of direction required. The wedges are now gently tapped with a heavy hammer, till all have got a hold; then harder blows are given in quick succession, and the fracture takes place.

a shows sketch of wedge, made of iron, and from 4 to 5 in. long and 1½ in. wide.

In coping or splitting granite, wedge holes are not cut as in stone, but circular holes are "jumped," 1 in. or 1¼ in. in diameter and about 5 in. deep, at distances apart varying with the obstinacy of the material, and plugs and feathers are inserted and driven in as for stone. The plug is of soft steel, and made tapering as at *c*.

The feathers are thin pieces of iron, concave in section, as shown at *c* 1. These are first put in the holes, the plugs are then driven in until they become tight, and a few sharp blows are all that is necessary to complete the process of splitting. *c* 1 is a plan of *c* to a larger size.

Fig. 28 shows a pair of iron lewises used in lifting worked stones for fixing. The lewis consists of a dovetail of three pieces, the two outer pieces being first inserted in the hole, and then the center piece, which acts as a key, and tightens up the dovetail; the shackle is next put on, and the bolt is passed through the whole.

Care must be taken to cut the hole to a dovetailed shape, and of the size of the lewis.

A is the front view and *B* is the side view, of the lewises.

Fig. 29. Shows an iron conical-shaped lewis plug, which is placed in a slightly larger dovetailed hole, a small curved iron plug being inserted by its side.

which keys it up. This is used chiefly for worked granite.

Fig. 30. A pair of chain lewises, consisting of two curved iron plugs with rings for chain; these are inserted in a dovetailed hole, and when tightened up act similarly to the ordinary lewises.

Fig. 31. A pair of iron dogs, or nippers, with steel-jointed claws, used for lifting rough blocks, and also for fixing.

Fig. 32. Axe, about 12 or 14 lbs. in weight, chisel-pointed, used on granite for removing the inequalities left by the pick and dressing it similarly to tooled work in stone, showing the marks or indents in parallel lines.

Fig. 33. Pick, about 16 lbs. weight, used chiefly on granite, for dressing the inequalities of the rough or rock face down to within 1 in. of the finished face; and also used for scabbling blocks of stone roughly to the required shape.

Fig. 34. Spalling hammer, about 12 to 14 lbs. weight. This has a square edge of about 1½ in., and is a very effectual tool for knocking off rough lumps.

Fig. 35. Patent axe; the body of this is of iron, with a slot at each end, into which a number of parallel thin plates of steel, chisel-sharpened and of equal length, are inserted and tightly bolted together. This is used for granite, and produces the finest description of face, next to polishing.

Fig. 36. A pair of trammel heads, or beam compasses, used chiefly for setting out arcs of circles ful' size; those made of gun-metal, with steel points, are the best, and a set should be large enough to take a rod 30 ft. long.

Fig. 37. A spirit level for fixing.

Trammel heads & Rod

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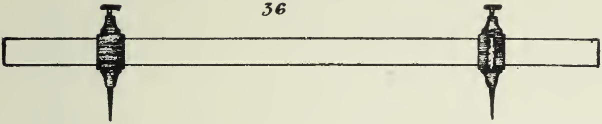
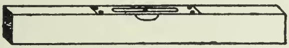


FIG. 37



LEVEL

C 1

a b c

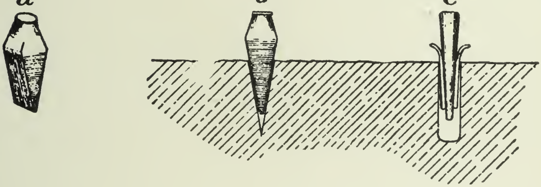
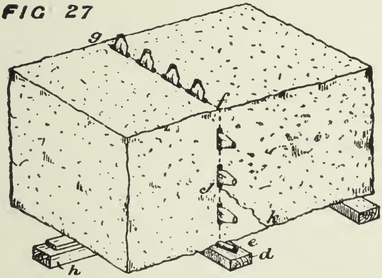


FIG. 38.

FIG 27



COPING OR SPLITTING BLOCK BY WEDGES

The following appliances are also required for setting out work:

A large platform or drawing board, about 10 or 12 ft. square; or if larger than this, the better. It may be fixed either vertically or horizontally.

A standard five-foot rod.

Two or three straight-edges of various lengths.

Pine rods for story rods, and for setting out lengths of cornices, modillions, dentils, etc.

Pipe-clay and stiff brush, for cleaning off board, rods, etc.

Sheet zinc for moulds, usually No. 9 gauge, this being a good workable thickness. The lines for face, bed, and section moulds have to be carefully transferred to the sheet zinc, and cut to their proper contour or shapes with shears and files.

The foregoing lists do not comprise all the tools and appliances required for every branch of masonry, but only those which are in common use.

All cutting tools are made of the best cast steel, except the pick, axe, and spalling hammer, which are sometimes of iron, steel pointed and faced.

NAMES OF WROUGHT STONE

There are three classes of stones made use of for building purposes; namely, rough stones as they are taken from the quarry, stones squared and dressed in a rough manner, stones dressed and squared accurately.

Stones, rough and left unsquared, are called "rubble." When stones are roughly squared and dressed, they may be "quarry faced"; that is, the face is left just as it came from the quarry; or it may be "pitched faced," or "rock faced," in which case the face will

project beyond the face of the joint; or it may be "drafted," in which the face is surrounded with a chisel draft to allow of the joints being flush on the face.

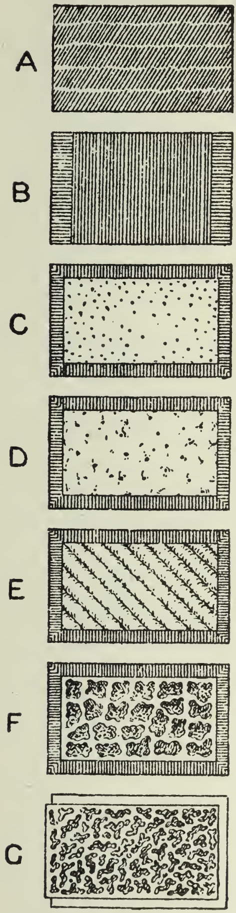


Fig. 39.

In cut and dressed stones, there are: 1, the rough pointed; 2, the fine pointed; 3, the crandaled; 4, the tooth axed; 5, bush hammered; 6, rubbed; 7, diamond paneled. There are also other finished stones, that will be discussed in future pages.

The illustrations (Fig. 39) show the different stones when finished. These exhibit the various forms of dressing stone commonly used.

A shows a boasted or chiseled face, sometimes termed droved work. The face is finished with a boaster, and the strokes are generally regular and parallel to each other.

In hard-grit stones this face is usually left as finished, and when, as in the case of a building, the whole of the ashlar and plain work is chiseled to the same angle of inclination, the effect is pleasing.

In softer stones a finished face is formed by rubbing the boasted face with sand and water, and removing all chisel marks; it is then called plain ashlar.

B shows ashlar with tooled face.

This is formed with a broad tool, or wide boaster, by a regular succession of strokes, parallel to each other, extending across the whole width of stone, and when finished shows a series of flutes or channels, the size of flutes depending on the texture of the stone.

Considerable skill is required in tooling neatly, and the tooling is somewhat costly, the surface having first to be worked to a boasted face.

C shows ashlar with pick or pecked face, and tooled margin.

This is produced with a point, or in the case of granite with the pick, and can be worked to any degree of fineness.

D shows ashlar with punched rock face, and tooled margin.

This is similar to the last mentioned, but much coarser. In producing it, the punch is driven in almost vertical to the face until the stone bursts out, leaving a series of cavities. When regularly done it looks well, and is very effective, and for large work it gives the appearance of boldness and solidity.

E shows ashlar with broached face, and tooled margin.

This is produced with a point, which forms a furrow with rough ridges, and is worked across the stone to the required angle.

F shows ashlar with rusticated face, and tooled margin.

This is worked with small chisels and points, and sunk down about half an inch, leaving a plain, narrow margin on face; the pattern is irregular, but easily adapted to any space.

G is a rebated or rustic quoin, with vermiculated face.

This is cut out with small chisels, and has the appearance of being worm-eaten.

In order to prepare the stones for dress finishing they must first be brought to a flat surface on one side. This flat surface or face may be "winding," or it may be a plain, flat surface similar to that shown in Figs. 40 and 41.

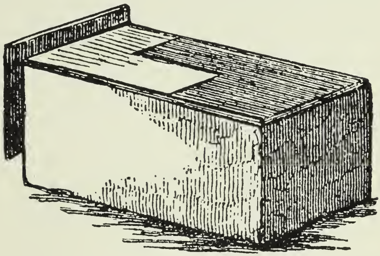


Fig. 40.

When the bed, or one plane surface, has been produced, the required shape of the sides of the block are marked upon the surface with the aid of a square or template. Drafts are then sunk by the chisel across the extremities of an adjacent face with the aid of a square (Fig. 40), or bevel if the sides are not to be at right angles to the bed, and a second face is obtained between such drafts. The process is repeated for the third face, and so on, until the block has been brought to the desired form.

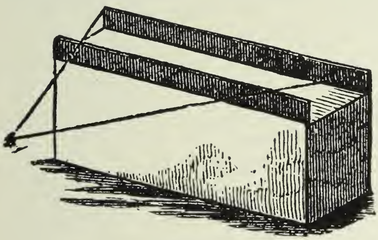


Fig. 41.

Regularly winding surfaces may be obtained in various ways. The simplest plan is when the stone is worked to the proper planes and angles, as just described, to set off the amount of the winding, A*a*, Fig. 42, on the arris and draw the drafts, lines *a*B, *a*C. A series of lines, as *be*, *cf*, *dg*, are then drawn parallel

with A*a*, and another series, *eh*, *fi*, *gk*, parallel to AC. The drafts being sunk at these, so that a straight edge coincides from *b* to *h*, or *c* to *i*, or *d* to *k*, the surface is wrought so that when the rule is applied parallel to the plane A*a* B, it may coincide with the surface at every point. If one end of the stone is less in length than the other, (Fig. 43), the line *a*B must be divided into equal parts, and the lines *be*, *cf*, *dg*, drawn parallel to A*a*. The line CD is then divided into the same number of equal parts in *h*, *i*, *k*; then *ch*, *fi*, *gk* are joined instead of being drawn parallel to AC. The drafts are then sunk until a straight edge agrees from *b* to *h*, and so on, and then the surface is dressed so that the straight edge will coincide in a direction parallel to the plane A*a* B.

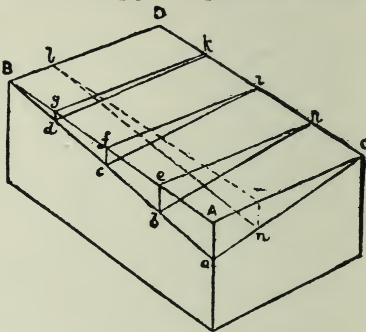


Fig. 42.

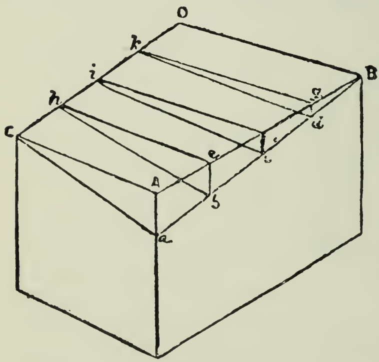


Fig. 43.

Winding surfaces may likewise be formed by the use of two rules, one having parallel and the other divergent edges. These are sunk in drafts across the two ends of the stone until their upper edges are out of winding. The ends of these drafts are then connected by means

of two others formed along the sides of the block, and the entire surface worked down to them until it coincides with a straight-edge placed in a direction parallel to the drafts. The rules used in this process are known as "twisting rules," one of which, as at A, Fig. 44, is, of course, simply a straight edge with parallel to opposite edges. The other, B, is termed a "winding strip," and that portion of it which coincides with the twist of the stone, as shown by the dotted lines, is, of necessity, a triangle.

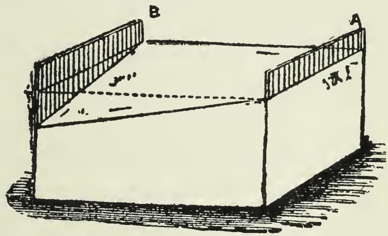


Fig. 44.

The formation of mouldings, columns and the work of the carver and sculptor, as well as that of the marble mason and statuary, form a special branch of the trade, which comprises the production of such parts as enriched cornices, capitals, etc., and is necessarily valued by the time expended upon it; the value of the time varying, in the higher class of carvings, with the artistic reputation of the man employed, and, as this work is not intended to teach the higher artistic phases of the art of masonry, such matter will be left to be dealt with in another volume that may follow this in the near future. The wall mason builds all stone constructions and, from the irregular shapes and sizes of the materials generally at his command for building purposes, is constantly called upon to exercise an amount of judgment and skill far beyond what is required to make a good bricklayer, who mostly lays his regular-shaped bricks according to fixed rules, which he knows

by heart, and ought not to depart from. The rougher the materials, the more skill is required in putting them together; whilst the greater the labor expended in dressing them to regular shapes, the easier is the task the wall mason has to perform.

Large face moulds are sometimes made of several pieces of timber framed together.

When the beds of the courses are to be plane and level they can be set correctly by the level and common straight-edge. When they are to be planes having a given shape a rule must be employed having two straight edges inclined to each other at such an angle that, when one edge is set horizontal by the spirit-level, the other has the proper inclination. If the beds of the courses are to be perpendicular to a straight or curved battering face, their position can be set out and tested by the square.

Curved beds, such as are employed for some special purposes, require the use of suitably curved bed moulds.

In all cases in which economy of time and money has to be studied, the workman should, as far as practicable, avoid curved figures in masonry; for not only are they more tedious and expensive to set out, and to build than straight and plane figures, but it is more difficult to test the accuracy with which they have been executed. A single glance will detect the smallest appreciable inaccuracy in a wall with a straight batter, while the same process in the case of a wall with a curved batter, would require either a long series of measurements, or the application of cumbrous face-mould to various parts of the wall; and this becomes a matter of serious importance in large structures, where errors in form may affect the strength and stability.

All stones, except under peculiar circumstances, should be laid on their *natural* or *quarry beds*, or with their natural beds as far as possible perpendicular to the pressure they have to bear. The strength and durability of the stone depends on this being done—even in cases in which the natural beds cannot be distinguished by an unpracticed eye—for few stones will bear the same pressure applied in the direction of their lines of stratification as at right angles to them; moreover, if the bed of a stone is exposed on the face of a wall, the water will get in between its layers, and frost will soon cause layer after layer to peel off; hence it follows that in projecting undercut mouldings and weathered coping the natural beds should be placed parallel to the side-joints.

The careful bonding of the masonry must be attended to. A wall built of the roughest stones ought to be perfectly stable, though no mortar is used.

The principles of bond, by the stones overlapping and breaking joint throughout the wall, are the same as in brickwork, and should be thoroughly understood by the mason, for upon their skillful application his reputation as a good waller depends.

All dry and porous stones should be well wetted before being laid in mortar, so as to absorb the moisture required for the proper setting of the mortar.

All joints should be filled up solid with mortar.

The thickness of the bed-joints, depending on the smoothness of the beds, must be sufficient to prevent any unequal bearing resulting from actual contact between any irregularities on them.

Where a good appearance is aimed at, all stones exposed to view should be selected free from stains, chiefly caused by oxides of iron.

Iron should never be placed in contact with stonework where, by rusting, it might disfigure it with stains, or split the stone by its increase in bulk during the process of oxidation, or by its expanding and contracting under the influence of heat and cold.

In order to understand the practical operations of building in stone, it is necessary to explain the different descriptions of masonry in ordinary use. These may, as before explained, be included under one of the three following heads, viz.: Rubble, Block-in-course, Ashlar.

If the stone at disposal is thinly bedded, rough or intractable, it should be used as rubble-work; if obtainable in blocks, and more or less easily wrought, it should be used as *block-in-course*, or *ashlar*, according to circumstances.

RUBBLE MASONRY

In *rubble-work* stones of irregular size and shape are laid in a wall, after having been more or less assorted, roughly shaped to fit one against another, and hammer-dressed on their faces with the waller's hammer, according to the quality of the work required.

In the rougher kinds of rubble-work no selecting of the stones takes place, but the waller, having once taken one up, places it in the wall as it will lie best, packing in smaller stones between the larger ones. The stones should be placed on their best beds, and not on their points, which would be liable to crush, in addition to the wedge-like action of such stone, in the interior of a wall, tending to dislodge the facework. No attention whatever is paid to the joints being more horizontal or vertical than naturally results from the bedding and cleavage of the stone used, upon which

the degree of regularity in the appearance of the work mainly depends.

In rubble masonry the rough nature of the work leaves many spaces between the joints, both on the face and interior of the wall; these should be carefully packed up or pinned with spalls, which are the pieces knocked off the rougher stones in order to get them to fit into place.

Care should be taken that the *hearting* or interior of a rubble wall is well packed with spalls and mortar,

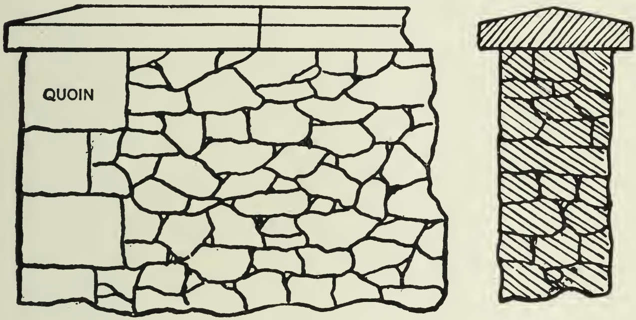


Fig. 45.

and not left full of hollows or mortar alone; to ascertain whether this has been done, take the waller's trowel and plunge it in different places into the heart of the wall.

The spalls must not be placed in the heart of the wall so as to drive like wedges when the weight from above comes on them, or the facing stones will be forced out.

Attention is necessary during the building of rubble, as well as all masonry walls, to insure their being well bonded transversely, and not built up with two thin

scales on each face, tied together by *through* stones, with the core or hearting merely filled in with small pieces. This is a very common fault with masons, who will rely upon the mortar to give stability to a wall which, without it, would fall to pieces under its own weight.

The best stones for rubble masonry are those that scabble freely, and such as lie in 4 or 5-inch beds. Basalts and stones of a crystalline structure are troublesome to use, as they fly under the hammer, but granite and sandstones work in well.

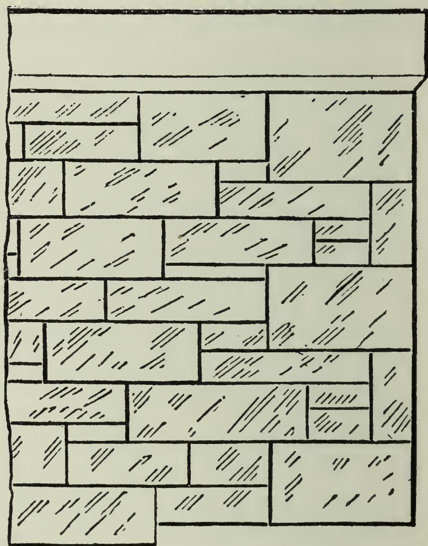


Fig. 46.

Rubble may be either *uncoursed*, *irregular* or *random coursed*, *worked up to courses*, or *coursed*, chiefly depending upon the character of the stone at disposal. Some stones, from their intractable nature, and the absence of any distinct lines of bedding, are especially adapted for uncoursed rubble (Fig. 45), whilst other stones have lines of layers or courses and therefore should be used in square rubble, as shown in Fig. 46.

A portion of a structure in random rubble is shown

in Fig. 47. This shows the quoins or corners in variously finished stones, all of which are named on the illustrations.

Random, common or rough rubble, built up to courses, is indicated in Fig. 48; the courses vary in depth from 12 to 18 inches. The remarks made above apply to this discription.

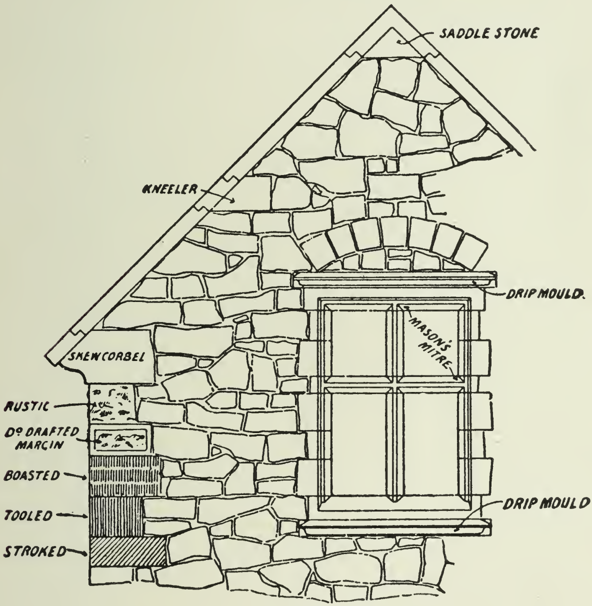


Fig. 47.

Square uncoursed, random coursed, irregular coursed, snecked or squared rubble, are five names implying practically the same description of work. It is shown in Fig. 49, A. There is a certain amount of coursing, but it is not regular or continuous; jumpers are used, but no spalls, and, if careful attention can be

given to bond, the strength of the wall is considerable.

Random with hammer-dressed joints and no spalls on face, or close-pricked polygonal ragwork, often called "cobweb" rubble, is shown in Fig. 49, C. Joints lie in all directions and considerable skill and experience are required to make good work. Freestone is seldom used in this description of walling, as it is chiefly formed with broken boulders, or field stones that have been split apart by dynamite or other explosives.

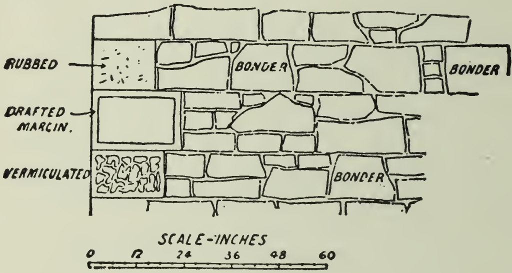


Fig. 48.

Regular coursed rubble (Fig. 49, D)—a very perfect bond can be obtained in this class of work. The courses often vary in depth, but are seldom more than 9 or 10 inches deep. Good stone found in thin beds in the quarry is commonly used.

Joints in any of these examples may be galleted by driving into them, from the face, chips of flint or hard stone.

Technical terms in connection with walling differ so much in different parts of the country that it is often advisable to build a small sample for reference in pricing quantities.

In the rougher descriptions of rubblework, lacing

courses are used to give the wall additional cohesive strength; they are two or more well-bonded courses of masonry or brickwork laid at short vertical intervals.

Block in course, or hammer-dressed ashlar (Figs. 50, A, and 51, A), is intermediate between the best rubble and ashlar. The coursing is regular, and the

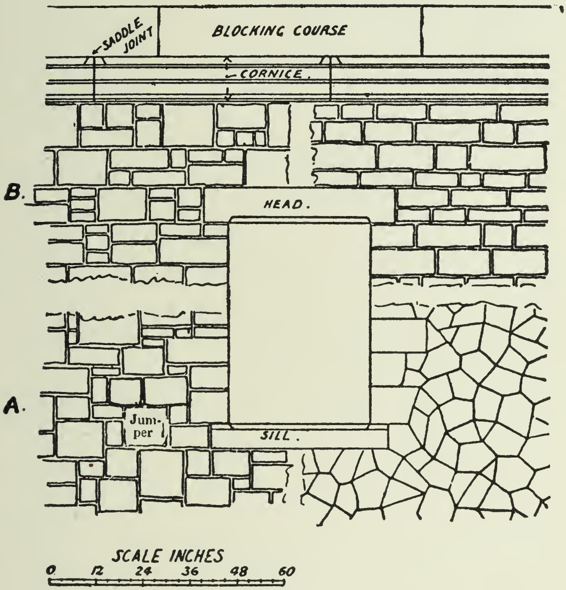


Fig. 49.

blocks are roughly squared; it is frequently constructed of shoddies, which are sound stones less than 12 inches deep. The length of each stone should be from three to five times its depth, and the breadth from one and a half to twice its depth. The exact proportions depend on the degree of resistance which the stone offers to

cross breaking. The same rules as to proportions apply to ashlar work

Ashlar is in large blocks, squared and regular in size, laid in courses varying in depth from about 10 to about 14 inches; the bed joints should be out of winding, but not smooth, and should never be worked slack (hollow on bed) and underpinned with spalls, as in Fig. 55,B; such a practice concentrates the weight on a small area, and leads to crushing or to the joints flushing, that is, the arrises breaking.

Fig. 50, A.

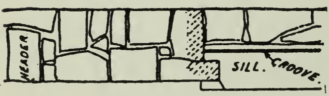


Fig. 51, A.

Joints should be as thin as the class of work allows, but never so as to leave an insufficient cushion of mortar to spread the pressure over the whole joint, as this would lead to flushed joints. Sheet lead has

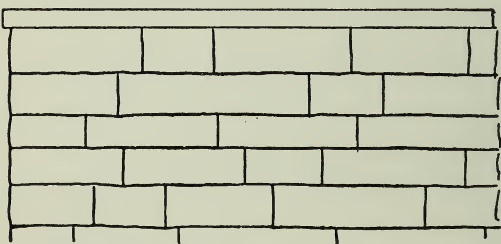


Fig. 51, B.

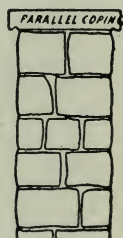
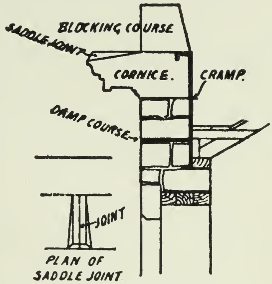


Fig. 52, B.

been inserted in joints subject to great pressure, to equalize it; but it is found that it squeezes outward and flushes the joints, thus more than counterbalancing any good it may do.

When the courses throughout the face of the build-

ing are all of the same depth, the ashlar is regular coursed (Figs. 52 and 53). If they vary in depth, it is irregular coursed; if the courses are not continuous, but broken, it is random ashlar, but the last class of work is unusual. The bond adopted follows the general idea of Flemish, but as all stones are not of the same size, considerable freedom is allowed in bonding, and, except in the best class of work, no attempt is made to keep the perpends. The courses should range with the quoin stones and dressings. Joints can be made less than one-eighth inch thick. Plasterer's putty is frequently used to make the outer part of the joint; it extends inward about two inches. Before being set, each stone



Figs. 52 and 53.

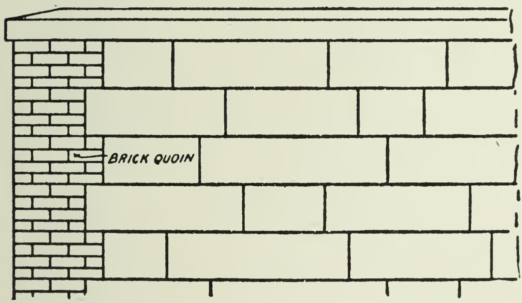


Fig. 52, A.

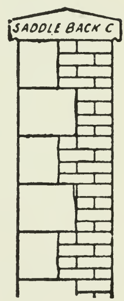


Fig. 53, A.

is laid dry in its place to ascertain that it truly fits. The amount of work on the face of ashlar varies very considerably; a drafted margin round a rough face is the minimum.

Rebated joints and V-joints are shown in Figs. 55,B, 54,B, and 55,B. They are used to emphasize the joints, and at the same time they prevent them from flushing.

Ashlar, so treated, is called rusticated.

A wall built of solid ashlar is necessarily costly, and the term has come almost to imply a facing of ashlar with a backing of rubble or brickwork. The ashlar is often only four inches and seldom more than six inches thick, with bond stones projecting into the backing.

Fig. 55,A. Fig. 55,B.

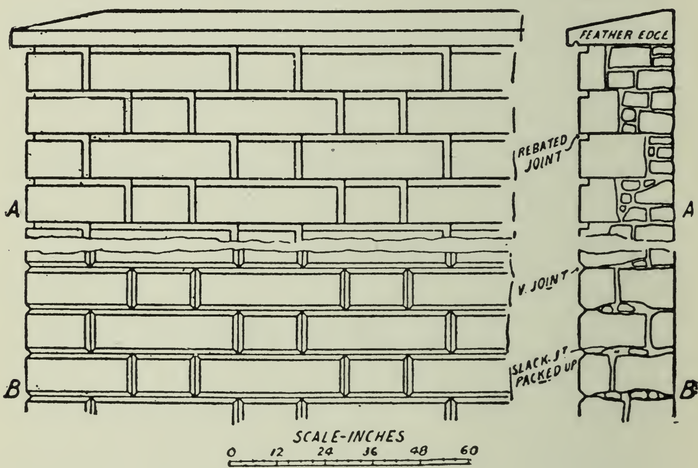


Fig. 54,B.

Figs. 52 and 53,A, show examples of brick ashlar and rubble ashlar. The ashlar should average about 8 inches on the bed, and should bond transversely with the backing. Headers of a length at least two-thirds of the thickness of the wall should be laid, one to every superficial yard of face. The backing, if of rubble, should be built in courses, each leveled up to

coincide with the ashlar courses. If of brick, the ashlar courses must be of suitable depth to allow of the same treatment. The greater number and greater thickness of the joints in the rubble or brickwork lead to more compression in the backing than in the facing, and this tends to cause the wall to bulge outward. This effect can be to a large extent avoided by building in cement or a quick setting mortar. Badly built walls of this description are very liable to collapse in case of fire, owing to the differing behavior under heat of the back and face.

Some may be roughly squared at the quarry; it is then said to be hammer dressed or quarry pitched. Afterward it is sawed to size, half sawing being charged to each of the two blocks produced by one cut. Sawing is now largely done by machinery. Plain work is the labor on a stone to "take it out of winding," or reduce it to a plane surface. Half plain work is similar, but is more roughly done, as for beds and joints. Self faced, natural faced, rock faced, are terms all of the same meaning, and indicate that the face of the stone is left rough as from the quarry, though it may have been scabbled with the hammer to remove irregular projections. A wall built of natural faced stone sometimes is called rustic face (see quoin stone in Fig. 47), but it must not be confounded with the rusticated joints mentioned above.

A stone is taken out of winding by cutting with the chisel a drafted margin along each edge of its face, as shown, and by means of a straight-edge bringing them all into a plane; the intervening space is then worked down to the same plane. If the plane surface be obtained by means of a point instead of a chisel, it is called pointed work; the drafted margin is, how-

ever, first made with the chisel. When the chisel marks are parallel and regular, but not continuous it is called boasted or droved work; when they are parallel, regular, and continuous, it is called tooled work. Stroked work is similar to the last, but the lines make an angle of 45 degrees with the edge. Soft stones are taken out of winding with a comb or drag, which often is merely a piece of a joiner's saw.

Rubbed work is plain work rubbed to a smooth surface; a rub stone is used with sand and water for this purpose. Some stones, such as marble, can afterwards be polished to a glassy surface. Vermiculated work is indicated in Fig. 39. Sunk work is any cutting below the plain surface, as in rebating or weatherings. Circular work is the labor required to form convex surfaces, as the shafts of columns. Circular sunk work is the labor required to form concave surfaces, as in stone channels. Circular circular work is the labor required to form such a surface as a sphere or a basin-shaped hollow. Moulded work is when a moulding of any profile is worked on the edge of a stone, as the cornice in Figs. 49 and 52. Circular moulded work is, in bills of quantities, always kept separate from straight, and is charged at a higher rate. Work is called stopped when the labor, whether sunk or moulded, is not continuous to the end of the stone, as the chamfer on the stone head in Fig. 49.

Quoins may be built of larger or differently worked stones from the remainder of the wall. A brick quoin may be built to a rubble wall, and more rarely to ashlar work, as in Fig. 51. In some varieties of rubble it is almost impossible to construct a sound quoin unless material superior to the bulk of the wall be used.

Ashlar work is constantly used for the dressings to

windows and doors in brick and rubble walls; Fig. 47 is an example. Reveals with recesses may be formed as in Figs. 50 and 51.

Stone window-sills for sashes and casements should be set to project about 2 inches from the wall face; they are weathered and throated, so that rain-water may run off the surface and drop clear of the wall beneath. They may be moulded on the front, and stools are worked on the ends for the brick or stone jambs to rest on.

To prevent water from being blown in between the stone sill and the wood sill resting on it, a water-tongue, usually of galvanized iron, 1⅛ in. by ¼ in., is set in a groove in the stone and wood; it and the wood sill should be bedded on the stone with white lead ground in oil. If sills are set flush with the wall, a separate drip mould (Fig. 47) should be fixed immediately below to serve the purpose of a throating.

Window-heads are made as wide on the bed as the reveal; the head of frame is behind them, with lintel (with or without relieving arch) over. A separate drip mould over the head, as in Fig. 47, protects it from water stains from above.

Coping stones are made in many forms, and are often handsomely moulded. As their purpose is to keep wet out of the wall, they should be chosen as nearly impervious to moisture as may be, cut in long lengths, say 5 feet or so, to reduce the number of joints, weathered and throated, and set and jointed in cement. These are respectively parallel saddle-back, and feather-edge coping; the first should only be used in inclined situations, as on gable walls. Raking copings are prevented from sliding by dowels built into the bed on which they rest. The same object is

served by kneelers, which are coping stones provided with horizontal tails (Fig. 47). There may be several of these in a large gable. Those at the foot are sometimes in the form of corbels (Fig. 47), when they are called skew corbels. The large triangular stone at the head of a gable (Fig. 47) is variously called summer stone, saddle stone, or ridge stone.

A cornice at the head of a wall (Figs. 49 and 52) may be one or more stones in height, moulded in front, and weathered and throated. There should always be sufficient tail weight for the stone to rest in its place without the assistance of the cement mortar in which it is bedded and jointed. Vertical cramps, say 2 in. by ½ in., 4 or 5 feet long, and one to each length of stone, or a blocking course, may be added to increase the stability.

In addition to mortar or cement, special connections, such as cramps, dowels and joggles, may be adopted for binding stones together; these terms are used rather loosely and sometimes interchangeably. A cramp is a connecting piece of metal, slate, or hard stone, so shaped that it holds two stones together. A dowel is a short, thick pin or narrow plate of metal, slate or stone, fitting into two sockets; it is sometimes called a plug, especially when fixed in the bed joint, or when it is formed by running molten lead into a dowel hole. Joggle is a comprehensive term, and includes all cases where a projection on one stone fits a corresponding sinking in the next.

Regular coursed rubble, as shown in Fig. 56, is applicable where the beds, though thin, are pretty regular, so that a sufficient number of stones of a uniform depth can be got to allow of their being laid in regular courses of one stone only in depth.

Dry rubble walling is the simplest class of rubble work, and consists of stones roughly hammered, and bedded by pinning spalls, without any mortar. It requires considerable skill to lay a wall up of this kind and keep it up straight and fair on both exteriors.

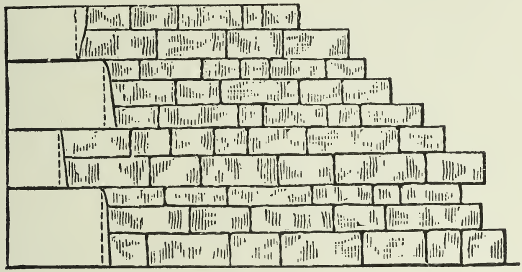


Fig. 56.

This kind of a wall should be wider at the base than at the top or coping. They are generally built to lines strained through trestles or horses, as shown in Fig. 57. This saves much time, as it avoids the necessity of plumbing the faces.

Dry rubble walling is generally built in courses about

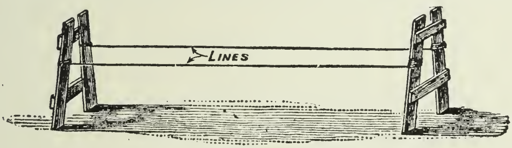


Fig. 57.

12 inches high, and should have a water proof top, or coping, to keep the water from getting into the body of the work and bursting it in frosty weather. The coping may be made of stones laid on edge in mortar (Fig. 58) of bituminous concrete, or, for want of anything better, clay puddle, or even sods.

Rubble ashlar consists of an ashlar stone face with rubble backing (Fig. 59), and is subject, even to a still greater extent than brick ashlar, to the evils caused by unequal settlement.

To avoid these evils, the stones and joints of the rubble backing should, as before mentioned, be made as nearly as possible of the same thickness as those in the ashlar facing, or, if the joints are necessarily thicker, there should be fewer of them, so that the total quantity of mortar in the backing and face may be about the same. This can seldom be economically arranged in practice, but it should be remembered that the more numerous and coarser the rubble joints, the worse the construction becomes.

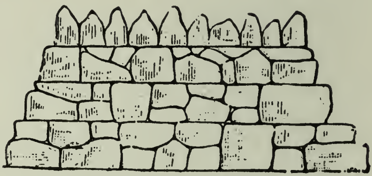


Fig. 58.

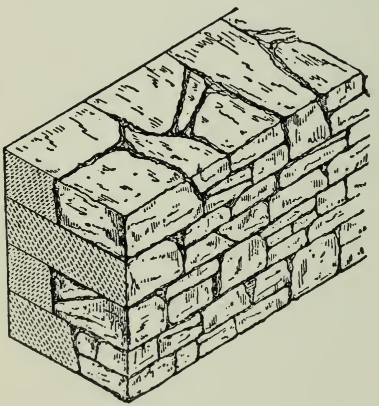


Fig. 59.

The ashlar should be bonded in with through stones or "headers," as previously described; their vertical joints should be carefully dressed for some distance in from the face, and their beds should be level throughout; the back joint and sides of the tails of the stones may, however, be left

rough; the latter may even taper in plan with advantage, and they should extend into the wall for unequal distances, so as to make a good bond with the rubble, the headers from which should reach well in between the bond stones of the ashlar. Through stones may be omitted altogether, headers being inserted at intervals on each side, extending about two-thirds across the thickness of the wall.

Fig. 60.

Care must be taken that the stones in the ashlar facing have a depth of bed at least equal to the height of the stone. In common work the facing often consists merely of slabs of stone having not more than from 4 to 6 inches bed, with a thin scale of rubble on the opposite side, the interval being filled in with small rubbish, or by a large quantity of mortar, which has been known to bulge the wall by its hydrostatic pressure.

Fig. 61.

The ashlar facing is in all respects, except those above mentioned, built as described in the section on ashlar, and the backing may be of random rubble done in courses from 10 to 14 inches high,

according to the depth of the stones in the facing.

The illustration, Fig. 59, shows the section of a wall 3 feet thick, with an ashlar facing composed of good substantial stone.

Irregular rubble, as before stated, is built up with split boulders, and when finished has an appearance as shown at Fig. 60. When a good face is formed and nice joints made, this kind of walling presents a very fine appearance.

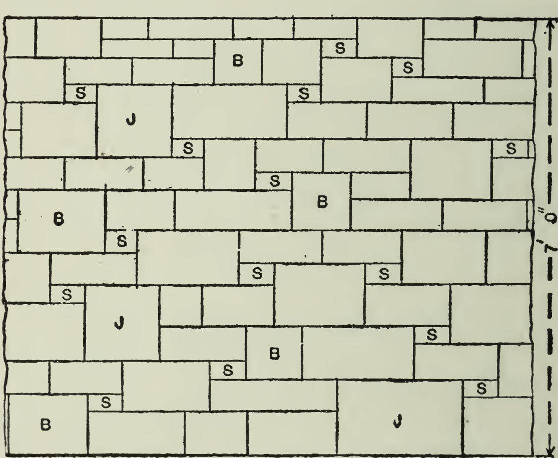


Fig. 62.

Coarse rubble without dressed quoins has an appearance similar to that shown in Fig. 61.

Snecked rubble is a method of building in which almost any size of dressed stones may be used. The stones marked Fig. 62, are jumpers, B are bonders, and S are snecks. Jumpers must not be used too freely in a wall of this description, or the wall will collapse, especially if any great weight is placed on the top of

the wall. Bonders should be evenly distributed throughout the whole wall in order to strengthen it, the name bonder showing that the stone goes through the wall to the inner face. Snecks, which determine the name of the wall, should be built in as often as possible. In a block joint two stones are butted against two stones, or two stones are butted against three stones (Fig. 63); or the stones are butted against each other without any attempt at bonding or breaking the joints.

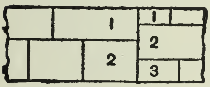


Fig. 63.

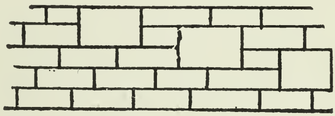


Fig. 64.

In Fig. 64 a common arrangement with single snecks beside each jumper is shown. In engineering works on a large scale, this is frequently done where a masonry wall has to resist forces likely to overturn, or having a tendency to overturn, the whole mass, or a part of it. It is claimed that the snecked work is stronger than coursed work, inasmuch as each jumper forms a vertical tie between two courses, and tends to prevent a too long horizontal course from yielding as a hinge.

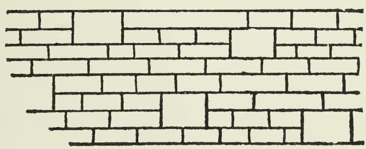


Fig. 65.

Some engineers seem to consider that single snecks place the jumpers too near to one another, and thus probably form a diagonal line of rupture. An arrangement like Fig. 65 may thus be preferred by some, giv-

ing a short course instead of a single sneck between each pair of jumpers.

Several of the vertical joints in Fig. 65, are badly arranged, tending to become perpends. Joints nearly vertical over one another should be separated either by a jumper or, if at all possible, by two ordinary courses.

A fault of some of the work executed is that it seems more like brickwork than masonry. There ought never to be the rigid regularity of brick bond in the face of a masonry wall. The regular irregularity—if we may so term it—of a well-built wall shows the skill of the craftsman, and is even appreciated by those able to judge as the correct placing and true economy of every cubic inch of material which the workman has had at his disposal.

Bond.—The best bond in masonry is that which shows on the face of the work alternate headers and stretchers in each course, as in Flemish bond in brickwork, each header coming over the center of a stretcher in the course below. In such work one-third of the face consists of headers, if the length of the stretchers is twice the breadth of the headers; but as stones are rarely cut to exactly the same dimensions, it may be laid down that not less than one-fourth of the face of the wall should consist of headers and that the stones should break joint from once to one and a half times the depth of the course.

Joints.—The thickness of the joint will vary from one-half to one-eighth of an inch, according to the smoothness of, or amount of work bestowed upon, the beds, as it must be sufficient to transmit the pressures from stone to stone, without permitting of actual contact at any point of their surfaces. The mason's joint,

or a properly struck joint, is the best which can be used.

Flush Joints.—Care should be taken to prevent the use of *flush* joints, which are formed by hollowing the beds below the plane of the chisel draughts run round the edges. This was sometimes done by the Greeks, in order to get perfectly close joints; but, by throwing all the pressure on the edges of the stones, they frequently splinter off and spoil the look of the work.

As flush joints cannot be detected after the stones are laid, the masons must be well looked after while at work upon them.

With a view of guarding against the splintering, or *spalling*, of the arrises of cut stonework, as in columns carrying heavy weights, seven or eight pounds sheet-lead is frequently placed between the stones. The lead, which is not allowed to reach within less than one inch of the edges of the stones, is thought to equalize the pressure over the beds by yielding to any slight irregularities on them, but the use of lead instead of mortar is a great mistake. It has been found that stones bedded on thin pieces of pine, instead of lead, equal in area to the bed-joint, bore a greater crushing force than stones double their sectional area bedded on lead in the usual way. The lead which had been used showed no signs of accommodating itself to the irregularities of the beds.

The joints of stone columns are often raked out about one inch deep, and pointed up when there is no longer any fear of their settling. The arrises of stones are also prevented from spalling by cutting them back, though this is generally done merely to give a bolder effect to certain parts, such as the quoins and lower stones of buildings.

Open Joints.—Open joints, resulting from projections beyond the plane of the chisel draughts, must also be avoided, especially in the beds, as tending to distribute the pressure unequally over them.

Rusticated Joints.—Rustic work properly applies to facework left rough from the hammer, though it also applies to a debased class of masonry, picked into deep holes, or honeycombed all over, to give a rough effect; but the term rustication, or rusticated, is also much used to denote masonry in which the joints are either chamfered, or sunk square below the facework.

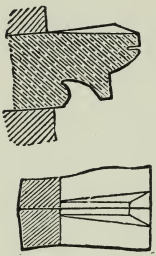


Fig. 66.

Saddle or Water-Joints.—In addition to the sloping off or weathering of the upper surfaces of stonework exposed to the rain, as in copings, cornices, and string courses, it is well to *saddle* the joints, by leaving them rather higher than the rest of the work, as in Fig. 66, in order to throw the rain away from the joints, and so prevent any water finding its way through them, and down the face of the work. Such joints are called *water-joints.*

Rebating.—The adhesion of mortar or cement, and the weight of the stones themselves, cannot always be relied upon as affording sufficient stability to stonework, especially when not built into the body of the work, where they would be held in place by the superincumbent weight; hence different methods are resorted to in order to give additional stability, such as *rebates*, *joggles*, *cramps*, *lead plugs*, etc.

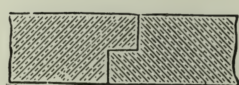


Fig. 67.

A rebated or lap joint (Fig. 67) is formed by cutting away a portion of the edge of each stone, so as to

allow them to lap over each other. Fig. 68 shows the proper way of making a rebated joint on a slope, as in the case of a barge course or coping on the gable end of a building; water is thus effectually kept out, which would not be the case if the side *a* were uppermost.

Joggling.—Stones are said to be joggled together when prevented from sliding by a projection or *he-joggle*, on one stone, fitting into a corresponding notch, or *she-joggle*, in the other stone (Fig. 69).

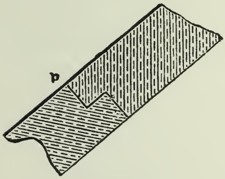


Fig. 68.

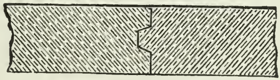


Fig. 69.

The he-joggle is generally cut square, and should taper slightly from the shoulder to the end, being stronger and easier to cut and fit into place when so made. If, instead of one or more square joggles, the joggling is continued along the joint, it becomes a *tongued and grooved joint*.

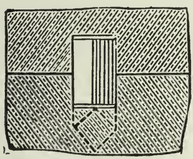


Fig. 70.

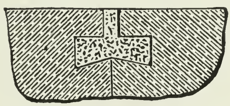


Fig. 71.

Doweling.—The above methods, except in special cases, as in Fig. 68, are wasteful both of labor and material; a better plan, therefore, is to sink, exactly opposite each other, two *she-joggles* or *dowel holes*, one in each stone, either circular or square in section, and fit into them a *dowel* or pin (Fig. 70), either of some

hard stone, such as greenstone, granite or slate, or of brass, zinc, or copper.

Copper dowels are the best, but very expensive; iron are the strongest, but should not be used unless perfectly secured from air and moisture, for fear of their cracking the stone during the process of oxidizing, and as an additional precaution they should be thoroughly tinned or galvanized.

There is nothing, perhaps, better, on the whole, than good hard slate dowels run with brimstone or cement.

Where very perfect workmanship is required, as well as when placed so as not to admit of being run in, the pins are made to fit the dowel holes accurately, being slightly tapered towards the ends, to secure a good fit and facilitate the setting of the stones.

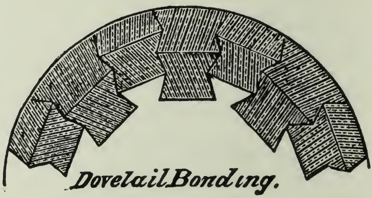


Fig. 72.

Lead Plugs.—In connecting stones by means of lead, plug holes, which may be dovetailed if thought necessary, are made, one in each stone, exactly opposite each other, as in Fig. 71, with a channel leading to them from the top of the joint, through which molten lead is run into them. The bottom of the plug holes should slope downwards, so as to carry the lead into them at once, as well as to give the stone a more secure hold of the lead. Great care should be taken in running in lead that there is no moisture in the holes, whicn, if suddenly converted into steam, might cause a serious accident.

Dovetail Bonding.—In masonry constructions intended to resist the shocks of waves, in addition to the methods given above, the stones may be held in posi-

tion by being dovetailed one into the other (Fig. 72), as was done by Smeaton at the Eddystone lighthouse; but good cement and dowels would no doubt be equally efficacious, and at the same time less expensive.

Tabling.—Stones of different courses may also be given great resistance to lateral shocks by *tabling* (Fig. 73), in which a flat projection cut on the bed of one stone fits into a corresponding sinking in the bed of the one under or overlying it. This method, however, is wasteful both of material and labor.

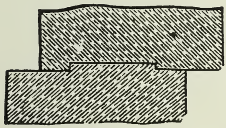


Fig. 73.

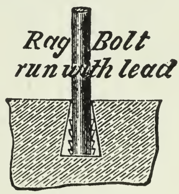


Fig. 74.

Securing Bolts, etc., in Stonework.—Iron bars and bolts are generally secured in stonework by being enlarged or jagged at the ends—bolts so made are called *rag-bolts*—let into dovetailed holes in the stone, and run with lead (Fig. 74). Brimstone is often preferred to lead, being cheaper and less liable to loosen by expansion and contraction.

Protecting Cut Stonework.—Any projecting or carved stonework in a building should be boxed up with rough boarding, after it has been set, to guard against its being injured by the carelessness of workmen, or by bricks, etc., falling from the scaffolding, during the progress of the work. The treads and nosings of steps should also be boarded over for the same reason, as well as to protect them from the rough traffic.

All the cut stonework should be well pointed and cleaned down before the building is given over for use.

ARCHES AND JOINTS

In the first part of this work, designs for many kinds of arches were given and described, and the rules given are in many cases applicable for stonework; so I will not burden this part with many examples, as those already exhibited, along with the few presented herewith, will be ample to serve the purposes of most workmen, and before proceeding further, it may not be out of place to explain a few of the terms that are made use of in connection with the construction of arches:

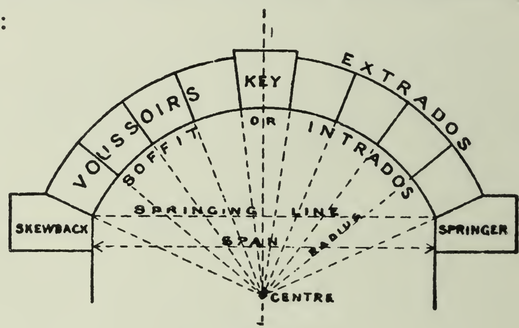


Fig. 75.

The face of the arch is the *front*, or that portion shown in elevation.

The *under surface* or *soffit* is called the *intrados*, and the outer surface the *extrados*.

The *voussoirs* are the separate arch blocks composing the arch, the central one being the *keystone*.

The *springers* are the first or bottom stones in the arch on either side, and commence with the curve of the arch.

The *skewbacks* generally apply to segmental arches, and are the stones from which an arch springs, and upon which the first arch stones are laid.

The *span* of the arch is the extreme width between the piers or opening; and the *springing line* is that which connects the two points where the intrados meets the imposts on either side.

The *radius* is the distance between the center and the curve of the arch.

The highest point in the intrados is called the *crown*, and the height of this point above the springing is termed the rise of the arch.

The *center* is a point or points from which the arch

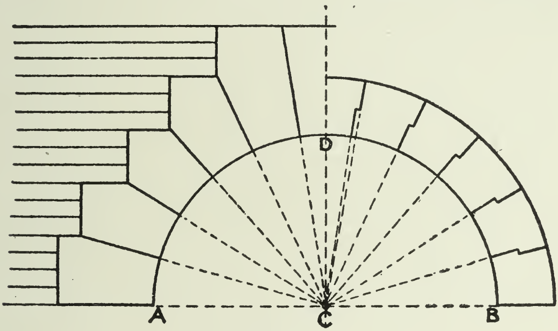


Fig. 76.

is struck; and lines drawn from this center or centers to the arch are radiating joints, and are also called *normals*.

All joints in arches should be radii of the circle, circles, or elipses forming the curve of the arch, and will therefore converge to the center or centers from which these are struck.

Fig. 75 shows a segmental arch, in which the abovementioned terms are illustrated.

Fig. 76 is a semicircular arch, *AB* being the span and *CD* the rise; the left-hand half has the ordinary joints radiating from the center *C*, and the right-hand half,

with rebated or step joints, also radiating from the center *C*. This last is a sound and effective joint where great strength is required, and there is also no tendency to sliding of the voussoirs.

Fig. 77 shows a semi-oval arch approaching in form that of the ellipse, and struck with three centers. This form of arch has a somewhat crippled appearance at the junction of the small and large curves, and is on that account not pleasing to the eye

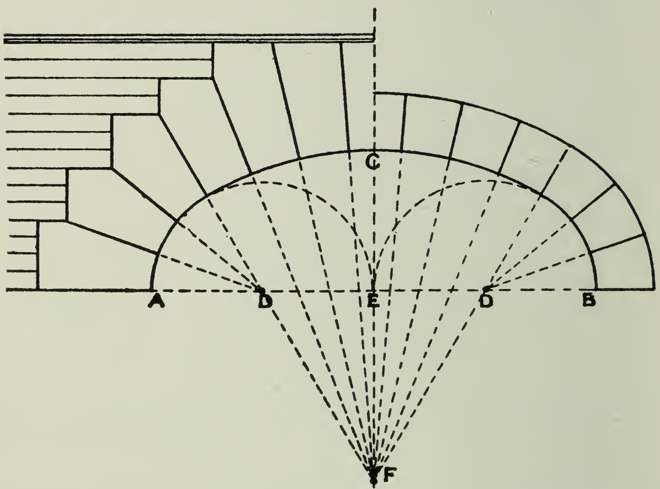


Fig. 77.

It may be here observed that the true ellipse is obtained from an oblique section of the cone, and no portion of its curve is any part of a circle, and cannot, therefore, be drawn by the compasses or from centers.

The method of setting out and drawing the joints requires but little explanation, *AB* being the span, *CE* the rise, and *DD* and *F* the centers, from which

the curve is struck, the joints converging to their respective centers.

The left-hand half is shown with square bonding on face, and the right-hand half shows line of extrados.

Fig. 78 is a Tudor arch, based on the curve of the hyperbola.

Let *AB* be the span and *CD* the rise of arch; erect perpendicular at *A*, and make it equal in height to two-fifths of the rise, as at *AC* and *CD*, each into six equal parts, and draw lines from 1 to 1, 2 to 2, 3 to 3, etc., and the line drawn through the intersections of

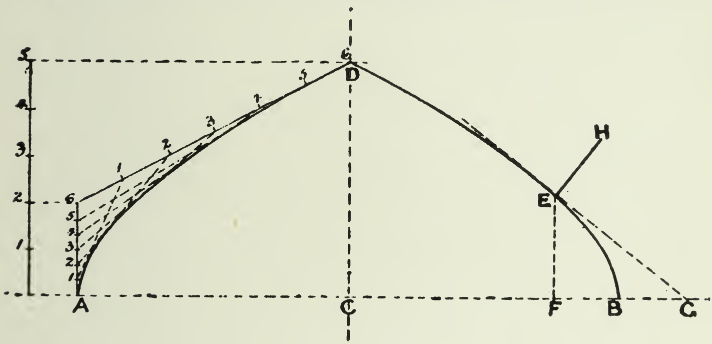


Fig. 78.

these points gives the curve of one side of the arch. The other side is obtained similarly.

A thin, flexible lath is generally used for guidance in drawing an easy curve through the points of intersection.

To draw the arch joints:

At any point in the curve, say at *E*, drop a perpendicular on to the springing line, as *F*, make *BG* equal *BF*, and from *G* draw line to *E*, which is tangent to the curve, and erect the perpendicular *EH*, giving the arch joint required.

The other joints are described in the same manner.

Fig. 79 is another example of the Tudor arch and is a parabolic curve.

Let *AB* be the span and *CD* the rise, erect a perpendicular at *A* and make it equal in height to half the rise, and proceed as in previous figure.

To draw the arch joints:

At any point in the curve, say at *E*, draw the chord line *BD*, and bisect it in *F*. Join *FG*, cutting the curve in *H*, and from the point *E* draw line *EJ* parallel to *EF*, cutting *FG* in *J*; on the line *FG* make *HK*

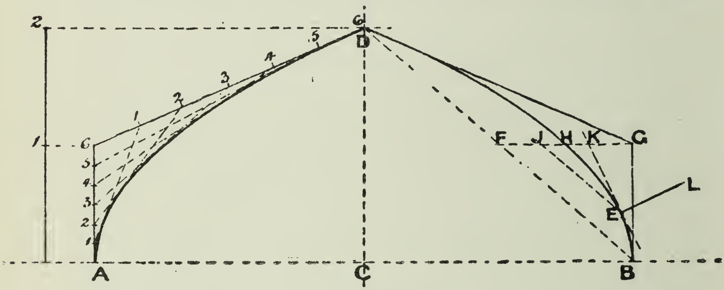


Fig. 79.

equal to *HJ*, join *EK* and draw *EL* perpendicular to *KE*, thus giving the joint line required.

The other joints are described in a similar manner.

Fig. 80 shows a straight or flat arch, the joints radiating to a common center.

On the right-hand half the joints are not continued through to soffit or top, but have a small portion squared on, thus relieving the acute angles of arch blocks, which are otherwise liable to fracture.

The springer on left hand has additional strength in having a square seating on skewback.

In flat arches a camber of an eighth of an inch in a

foot to soffit is usually given to allow for any depression or settlement.

Fig. 81 is another example of the flat arch; the left-hand half has rebated or step joints, and the right-hand half has joggle joints. All these joints converge to a common center.

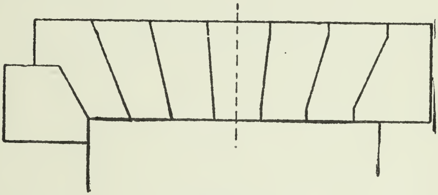


Fig. 80.

Fig. 82. — In this figure a lintel with double joggle vertical joint is given.

Fig. 83 shows a lintel with curved joggle joints, and is an example not often met with.

The form of joint in Figs. 81, 82 and 83 is a little wasteful of material; but where stone is plentiful and in small blocks, good lintels may be obtained. Many examples of these may be seen in our modern Gothic buildings.

Fig. 84 illustrates a window or door head with quadrant corners; the stretching-piece or key is in one stone, with arch-joints resting on the skewbacks.

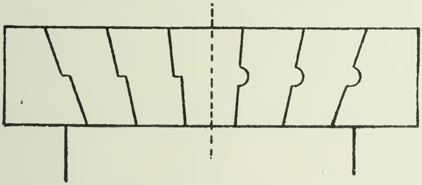


Fig. 81.

Fig. 85 is another form of head, the square seating in each stone giving additional strength, and the joints converge to common centers.

Fig. 86 shows three joints used in landings.

A is a joggle joint, commonly called he and she-

joggle. A tongue is cut slightly tapering on one edge, fitting into a corresponding groove worked in the other edge. Run in with cement, it forms a strong and secure joint.

B is a rebated joint; this is sometimes undercut.

C is a bird's-mouth joint. Grooves are roughly cut in on the edges of these joints opposite each other, and the cavities run with cement grout. Slate dowels are also laid longitudinally in the joint and run with cement.

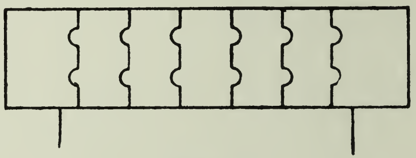


Fig. 82.

Fig 87 is a horizontal lintel or architrave spanning an opening, with an apparent vertical joint, but concealing a secret arch joint. This is used chiefly in colonnades, porticoes, etc., where stones of a sufficient length are not attainable, and sometimes also for convenience of hoisting and fixing.

An indent is formed the shape of the reverse of a wedge in joint of abutment, and a wedge-shaped projection is cut in keystone, fitting neatly into the indent.

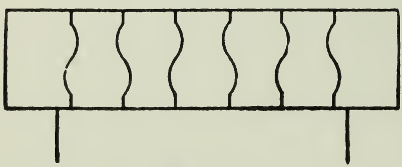


Fig. 83.

This makes a good and secure joint without doweling or cramping.

Fig. 88 shows sketch of weather or saddle joint in cornice. This joint is made by leaving at each end of the stone a ridge or roll, the formation of which is generally left till after fixing. This roll effectually prevents the water running through the joint. The

roll is not usually seen from the front, as the nose of cornice is continued straight through the joint, although it is also in some cases made a feature of.

This joint is used chiefly for cornices and window sills where there is a large projection.

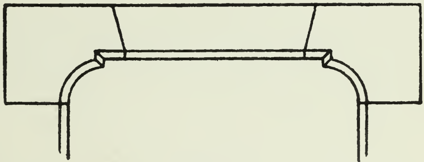


Fig. 84.

Fig. 89 exhibits a rebated joint in gable coping.

This joint is serviceable, inasmuch as it keeps the water out of the joint and the wall dry, although it is somewhat expensive.

Fig. 90 is an example of various bed joints in stone spires, being respectively:

A. A horizontal bed joint.
B. A bed joint at right angles to batter
C. A rebated or stepped bed joint.
D. A joggle or tabled joint.

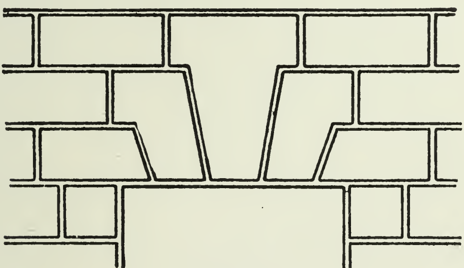


Fig. 85.

The bed joints of the stones are usually cut at right angles to the batter or face of the spire, as at B; but horizontal beds, as at A, are supposed not to involve so much thrust at the base. But for obviating any

outward tendency, a chain or rod-bond, united at the angles and inserted in a cavity at the base of the spire, is sometimes used.

The two bed joints C and D are both a little wasteful of material, but for stability and strength these are by far the best form of joints.

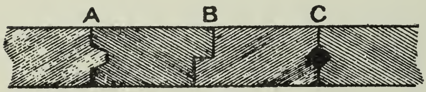


Fig. 86.

A word may be said as to the thickness of the work; this will depend chiefly on the height of the spire and the quality of the stone. From ten or twelve inches at

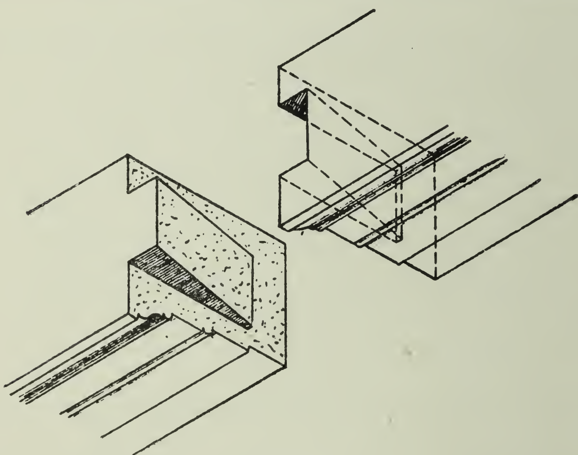


Fig. 87.

the base, diminishing to six inches or even less at the top, may be generally considered sufficient.

The stonework of the spire of Salisbury Cathedral (the spire, reckoning from the tower, being 204 feet in height) is two feet thick at the base, and gradually

diminishes in thickness to about twenty feet above the tower, where it is reduced to nine inches, and is continued at that thickness to the capstone at the summit.

Fig. 91 shows ashlar in courses with joggle joints. This is a very unusual form of joint, and is used, no doubt, more for effect than utility. There is a waste of material and labor, and a better result may be obtained by the use of slate cramps. However, there are some examples of it in modern buildings.

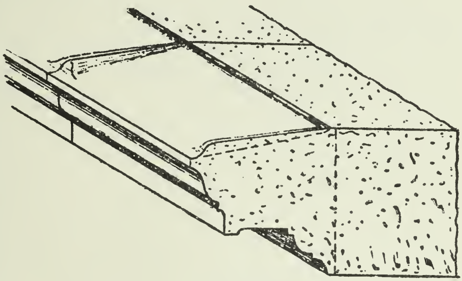


Fig. 88.

Fig. 92 is a seating to sill, with a slate or copper dowel to prevent lateral motion. Mortises are cut opposite to each other in the two beds, and the dowel made secure by being run in with cement.

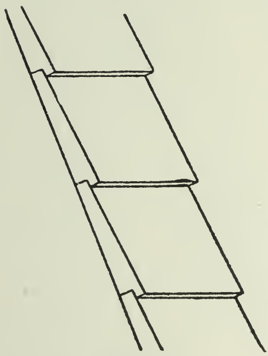


Fig. 89.

The dowel is a most useful adjunct in good and secure fixing.

Fig. 93, A, is a metal cramp for securing joints together. A chase or groove is cut in the stone of a sufficient width and depth, and at each end a mortise hole is cut to the exact size of inside of cramp, so that it fits tightly and requires to be tapped into its place; it is then run with melted brimstone or cement.

The use of iron cramps and dowels in connection with stone is generally attended with some danger, on account of the iron rusting, which causes an increase in size, and subsequent fractures and discoloration of the stone. But if the iron is properly protected by galvanizing or japanning, the risk is reduced to a minimum.

The best metals for cramps, dowels, etc., are copper, gun metal, or brass, but these are expensive and are therefore not much used.

B is an example of a slate cramp also used for connecting joints together, and is an excellent and economical substitute for metal. It is made dovetail in shape, let in flush to the bed of the stone, and then run in with cement.

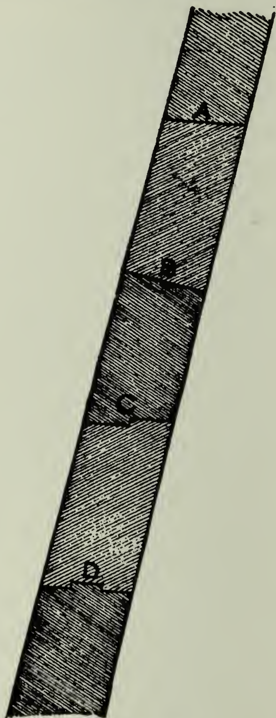


Fig. 90.

Fig. 94 shows a plugged or lead doweled joint. This is chiefly used in copings, curbs, strings, arches, etc., and prevents the joint working loose or "drawing."

Two holes, dovetail in shape, are sunk in the joints opposite each other and a small groove is cut from the top to each hole and run in with cement

Slate dowels are sometimes used for this purpose, and run in with cement.

Fig. 95 shows a lewis, or holding-down bolt, let in a dovetail hole and run in with lead.

The openings in stone of small span arches are generally bridged by stone lintels in one piece, or lintels built on an arched construction if a number of

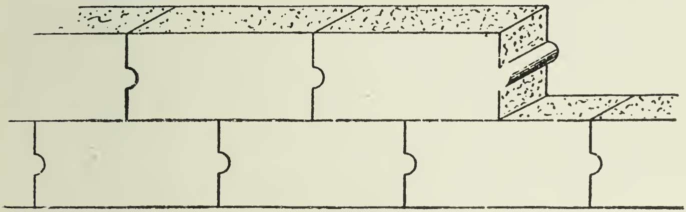


Fig. 91.

stones are used. If lintels of one piece are employed in walls other than ashlar, a rough arch is generally built above to relieve the lintel of the weight of the superincumbent wall, as shown in Figs. 96 to 98. A

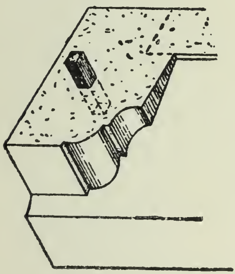


Fig. 92.

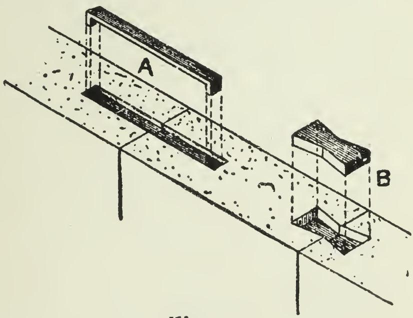


Fig. 93.

second method of relieving the lintel, commonly adopted in snecked rubble work, is to construct a flat arch of three stones above the lintel, as shown in Figs. 99 to 101; the center stone or key is termed the save. In bedding the save stones no mortar is placed on the

lintel, but the stones are supported in their position by means of small wood wedges. After a sufficient mass of the wall has been built to tail down the side saves, the wedges are removed. In finishing the wall, the joint between the saves and the lintel is pointed only; thus no weight from the wall above is brought to bear on the lintel.

A large number of stone openings are formed with flat heads, and where stones of sufficient dimensions cannot conveniently be obtained in one piece, some form of flat arch is adopted.

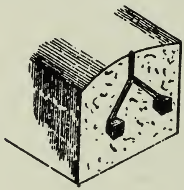


Fig. 94.

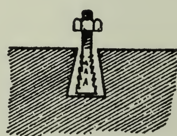


Fig. 95.

Figs. 102 to 105 show a flat arch, with secret joggles. These latter are worked out of the solid stone, the key having two joggles; the springer is recessed only, and is made sufficiently long to tail well into the wall, the remaining voussoirs being joggled on one bed-joint and recessed on the other; the cornice over window in this example is supported by a console or bracket.

Figs. 106 to 108 show the construction as a flat arch, the bed-joints stepped to prevent any voussoir sliding on its bed-joint. This method is largely used for terra-cotta work. This example illustrates an architrave about window, supported at sides by a half column with cushion frieze and segmental pediment above. The internal jambs are splayed, and illustrate

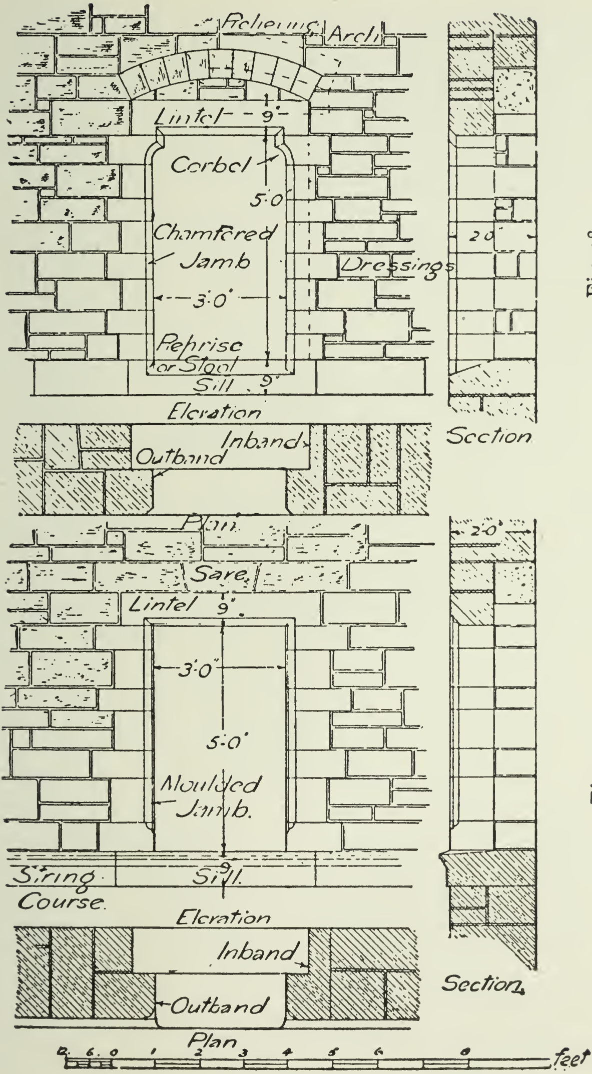


Fig. 96.

Fig. 97.

Fig. 98.

Fig. 99.

Fig. 100

Fig. 101.

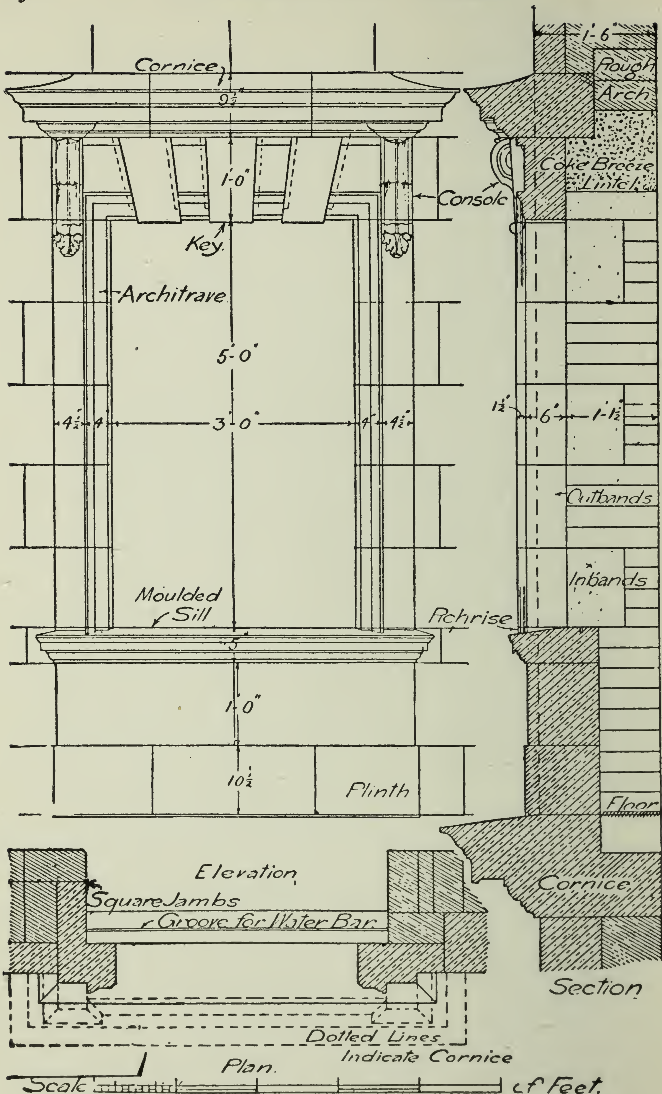


Fig. 102. Fig. 104. Fig. 105.

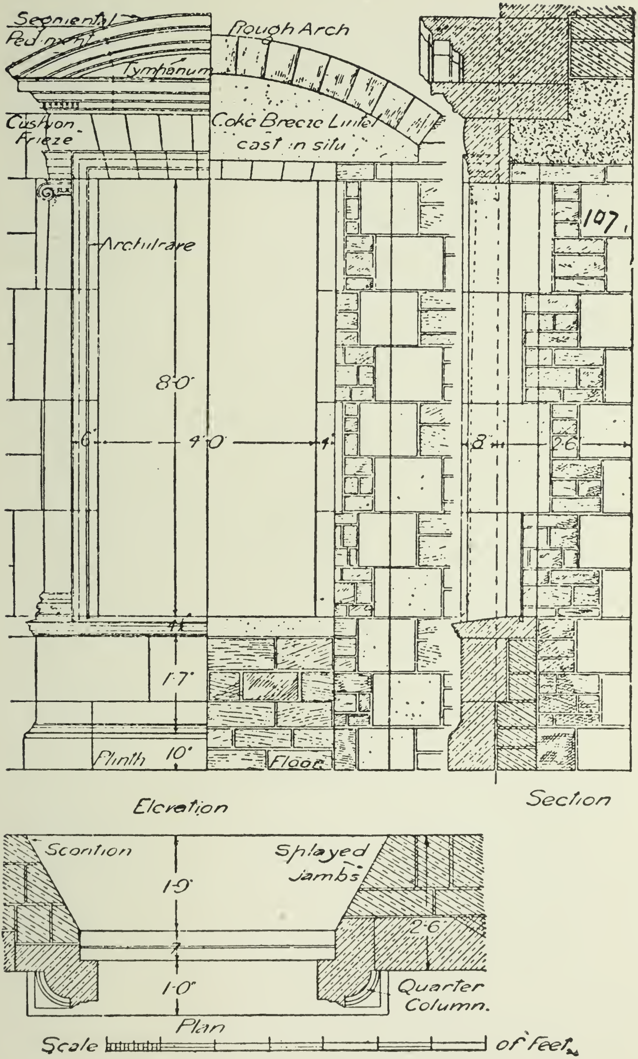
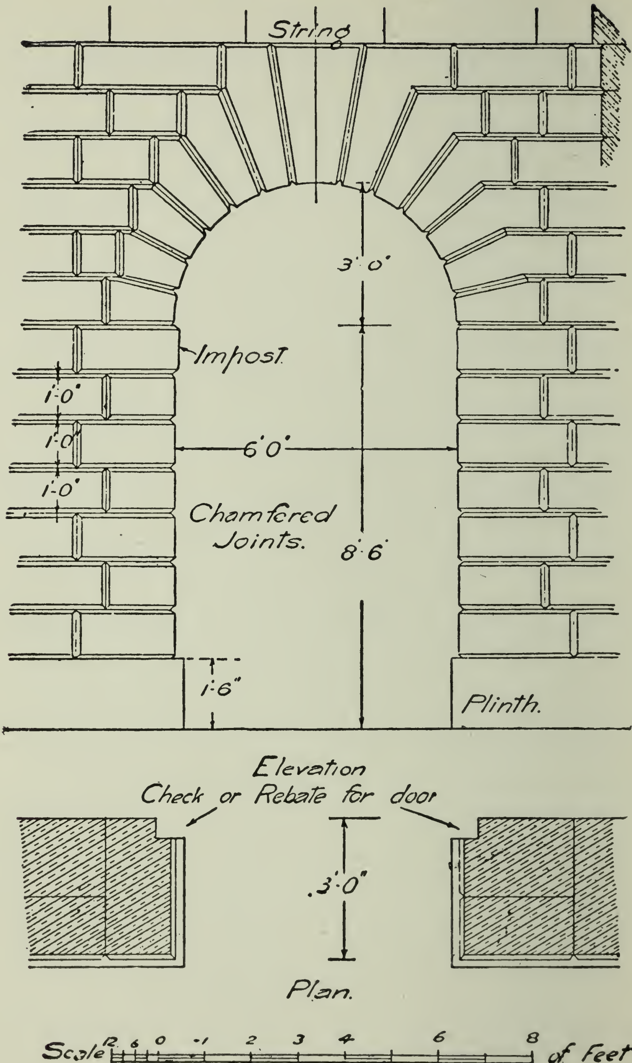


Fig. 106. Fig. 108. Fig. 107.



Figs. 109 and 110.

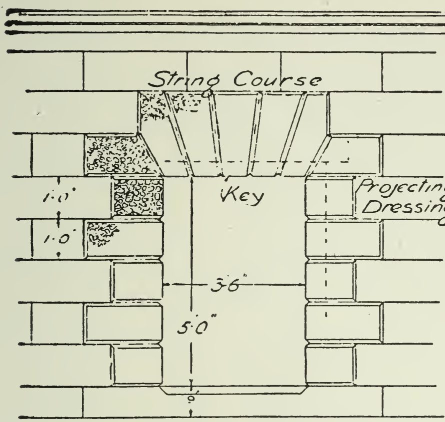


Fig. 111.

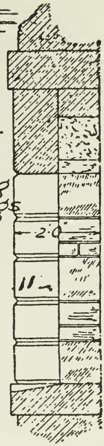


Fig. 112.

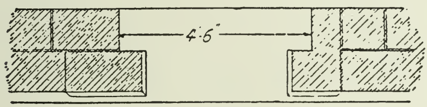


Fig. 113.

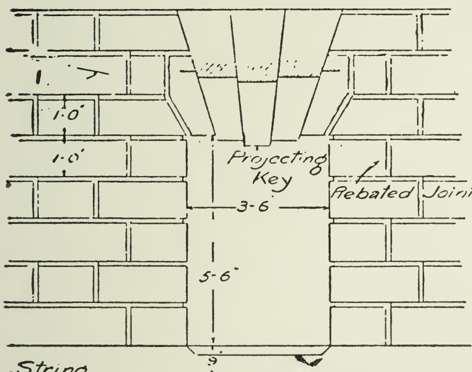


Fig 114.

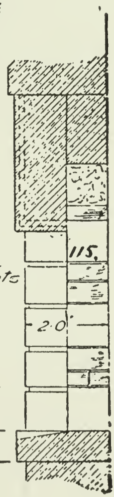


Fig. 115.

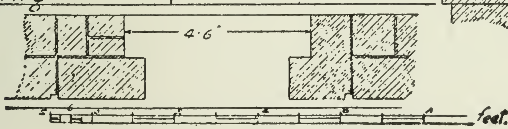
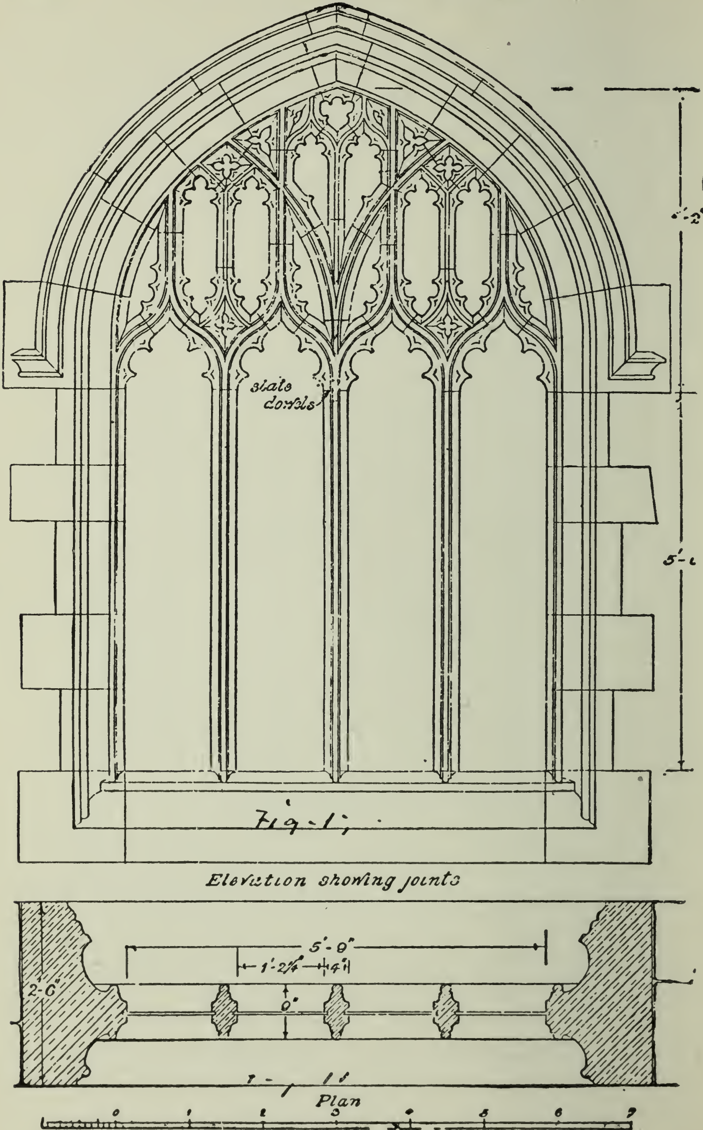


Fig. 116.



Figs. 117 and 118.

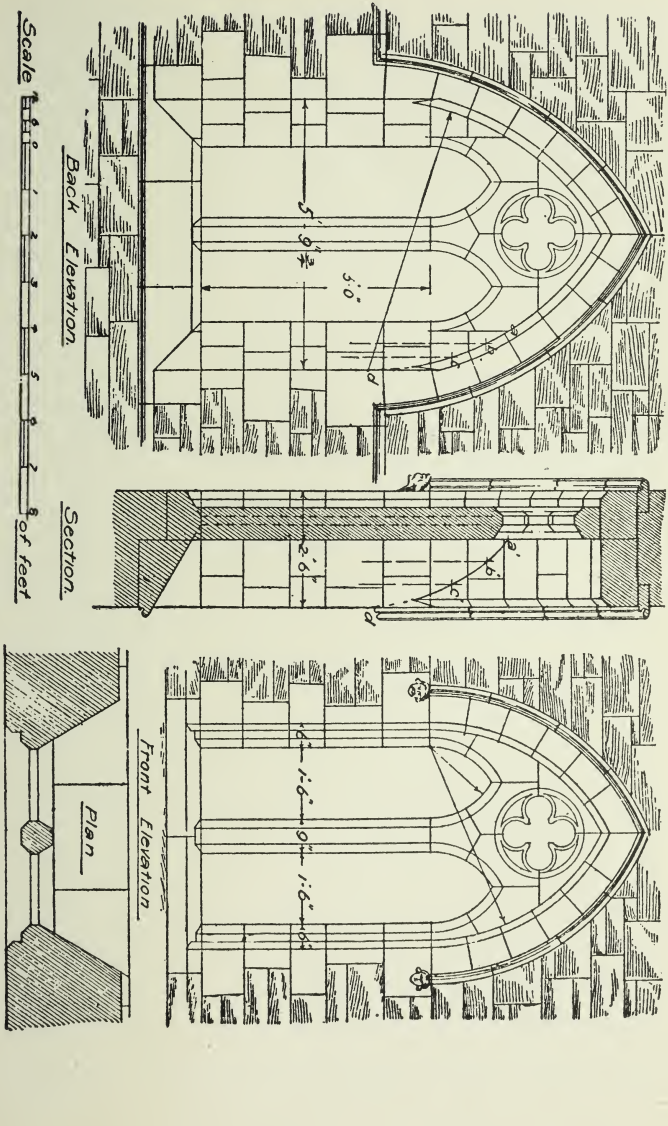


Fig. 119.

Fig. 120.

Figs. 121 and 122.

Fig. 123. Fig. 124.

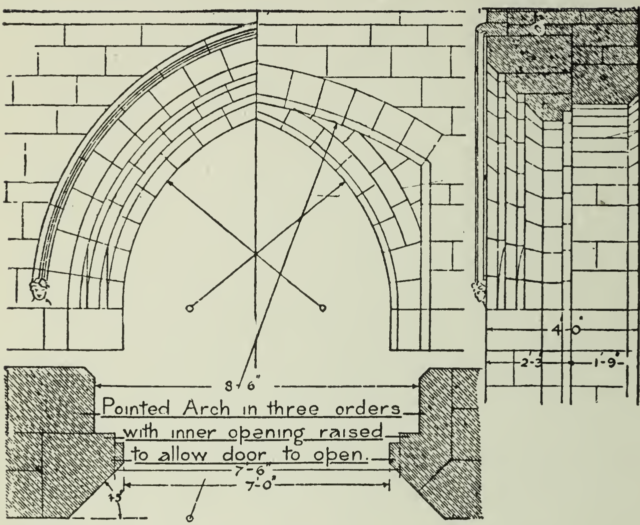


Fig. 125. Fig. 126.

the use of sconcheons. A coke breeze lintel case *in situ* is shown over the internal opening. Figs. 109 and 110 illustrate a semicircular opening in an ashlar wall, the blocks of which have chamfered joints. In these arches it is necessary to extend the bed joints of the voussoirs till they intersect the courses of the work; this results in the voussoirs gradually getting longer as they approach the key. Another method of arranging voussoirs is shown on right hand of Fig. 109. In this the bed joints of the voussoirs are extended to meet the horizontal courses, and are then returned a convenient distance along the horizontal course; this prevents the vertical joints of the voussoirs coming too close together near the springing.

Figs. 111 to 113 show a rectangular opening, spanned by an arch, the dressings and voussoirs of which project beyond the wall face about 1½ inches, have chamfered joints, and are vermiculated on surface to give importance to the opening; this form of opening is commonly adopted in the basement stories of classical buildings.

Figs. 114 to 116 show a similar opening, the voussoirs projecting as they approach the key and the joints of the masonry being rebated. This is also used for basement stories of classical buildings.

Stone being a granular material, anything approaching an acute angle is liable to weather badly; therefore in any tracery work, having several bars intersecting, a stone must be arranged to contain the intersections and a short length of each bar, as shown in Fig. 117, and the joints should be (*a*) at right angles to the directions of the abutting bars if straight, or (*b*) in the direction of a normal to any adjacent curved bar. This not only prevents any acute angles occurring, as would be the case if the joints were made along the line of intersection of the moulding, but also ensures a better finish, as the intersection line can be carved more neatly with the chisel, and is more lasting than would be the case if a mortar joint occurred along the above line. In no case, either in tracery, string courses, or other moulding, should a joint occur at any miter line (Fig. 118).

Figs. 119 to 122 illustrate the jointing and building up of a pointed arch with plate tracery and a rere-arch. Figs. 123 to 126, illustrate a pointed arch in three orders. with inner opening raised to allow door to open.

Tracery.—Wherever the moulded members of **the**

tracery admit of it, the practice should be followed of designing the tracery and fitting in rebated stone reveals, similar to the method of fixing wood frames in reveals, as it is found to be easier to fix the tracery after the opening is built.

STONE STAIRS AND STEPS

These consist of a number of blocks, fixed at regular and convenient heights, to facilitate transit between planes of different levels, and are of three kinds: (1) those stairs supported at both extremities; (2) those fixed at one end, (the other end being left free), and known as hanging steps; (3) steps circular in plan. These latter are divided into two classes: (1) those with a central newel; (2) those with an open well.

The steps may be in one of two forms, either rectangular or spandrel, as shown in Fig. 127. In the commoner stairs the rectangular blocks are used, but where a good appearance is desired or to gain head-room, spandrel steps are employed. The spandrel steps may be finished in one of three ways: (1) with a plain soffit, which consists in finishing the soffit in one plain surface, as shown in Fig. 127; (2) a broken soffit may be employed, as shown in Fig. 127; this is used for one of three reasons, or for all combined: (*a*) to gain strength at the back of the tread; (*b*) to save the expense incurred in working the surface of each step perfectly level; (*c*) to obtain effect; (3) having the soffit moulded.

Each step may simply rest upon the one below it, but it is usual for the upper step to be rebated over the back of the one below to prevent sliding. To avoid acute angles at this point, and to form an abut-

ting surface, particularly in the spandrel steps, a chamfer is taken off the top back edge of the lower step at right angles to the pitch of the stairs, the upper step having a corresponding sinking to fit. This is known as a back joint, and is shown in Fig. 127.

Fixing the Steps.—Stone stairs are erected in one of two ways: (1) they may be built in the walls as the latter are built, or (2) spaces may be left in the walls

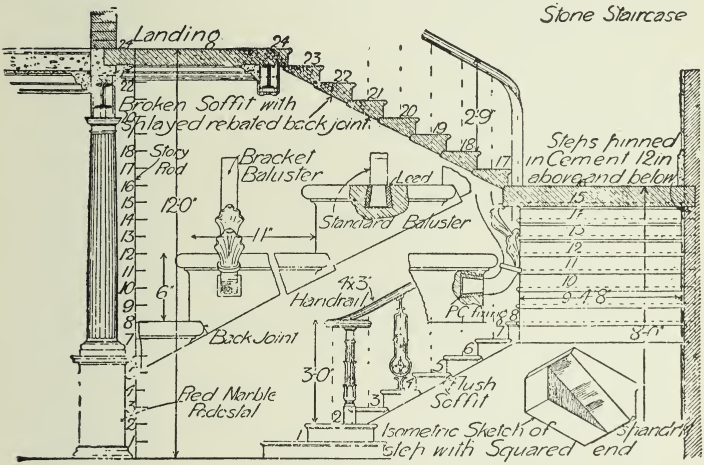


Fig. 127.

to receive the ends of the steps, which are fitted and fixed when the wall is finished. The wall should be built in cement mortar for at least 12 inches above and below the line of the stairs, the gaps to receive the stairs being temporarily filled up by brickwork bedded in sand.

The ends of the steps should be pinned in the walls with tiles or slates set in cement, care being taken that the space left about the end of the step is filled up, as

far as possible, with solid material, leaving no thick mortar joints to squeeze out. While the steps are setting, the outer or free end should be supported with wood struts, after being leveled, which should remain until the cement has thoroughly set.

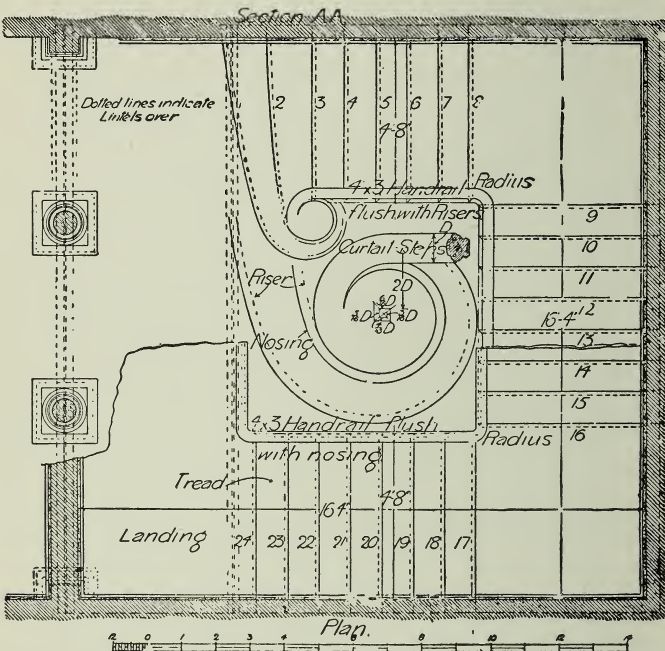


Fig. 128.

The first kind of stair, viz., those supported at both ends, combine convenience with the greatest strength. They are much used in schools, theaters, and other public buildings. They are usually made of rectangular steps, which rest six inches on the wall at either extremity.

The second kind, or hanging steps, are much superior in appearance to those last described. They derive their chief support from the walls, but each step receives an additional amount from the one directly beneath it. These are used for all conditions of stairs, from the secondary staircases in dwelling-houses to the grand staircases in public buildings. In the commoner kinds, rectangular steps are used; but in the superior, spandrel steps are always employed.

The steps may be plain or have moulded nosings; where the latter are employed, the moulding should be returned about the free end, the moulding on the latter being returned and stopped directly beneath the riser of the steps above, as shown in Fig. 127.

When the staircases are very wide, it is advisable to support the steps at their outer ends by steel joists or cantilevers at intervals, the strength of stone under cross stress not being very great. Fig. 127 shows a landing supported by a joist.

The first of the third class of stair, the circular newel, is used for turret steps; they are built in a circular chamber. The steps are wedge-shaped, their thin end being worked circular to a radius of about 3 inches, the front edge of each step being tangent to this circle, the back edge of the step being a radial line. The steps are built into the walls of the chamber, at their wide ends, each of the circular ends being arranged to fall directly over the one beneath it, thus forming a continuous newel up the center. These form a strong stair, but are rather dangerous, as they have to be steeply pitched to gain the necessary head-room.

Secondly, those formed with an open well are built in the same manner as the hanging stair, of which they form one variety. Stairs, circular and elliptical in

plan, are often built between two walls, as in the first class of stair.

Large stone landings which cannot be obtained out of one piece of stone are joggled at their joints, and where the slabs are thin and are likely to be subjected to heavy traffic, should be supported by steel girders.

The balusters in stone staircases are always of iron, which is better for fixing purposes. There are two methods of fixing balusters: (1) fixing them into the top, suitable for standard balusters, as shown in Fig. 127; (2) fixing them into the side, when they are termed bracket balusters, as shown in Fig 127. Holes are bored in the steps at the proper intervals, being slightly undercut. The ends of the balusters are indented before being inserted; they may be fixed in with lead, Portland cement, sulphur, and sand, or asphalt, as previously described.

Figs. 127 and 128 show plan, elevation, and details for an open well hanging stair, built of good hard stone. The lower flight shows handrail supported by standard balusters, the upper portion with bracket balusters to obtain the maximum quantity of available stair space. The method of setting out a scroll and curtail step is shown.

Stone Roof.—Fig. 129 shows the method of forming a stone-covered roof over a vaulted chamber, such as was frequently used during medieval times in military and monumental buildings. It is formed of stone flags bedded on rubble filling over the vault. In these roofs the flags are laid in two systems, the lower and the upper; in the first the flags are spaced apart, in the second the flags are bedded with a lap of 2 or 3 inches over the top edges of the flags in the first system. The whole upper surface has a slight fall for drainage.

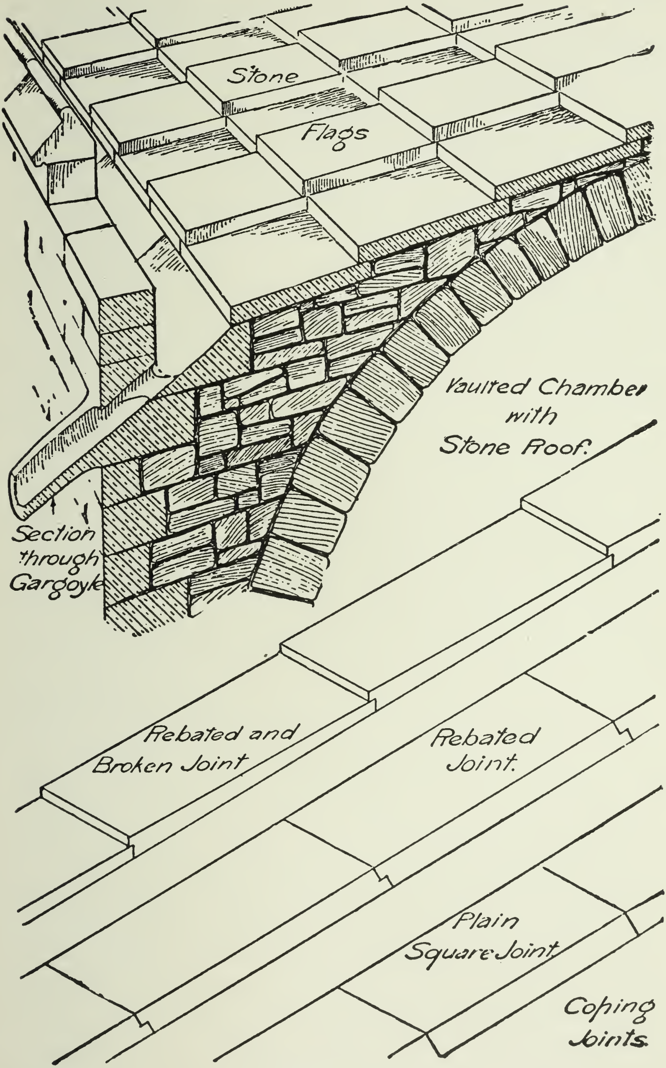

Stone
Flags
Vaulted Chamber
with
Stone Roof.
Section
through
Gargoyle
Rebated and
Broken Joint
Rebated
Joint.
Plain
Square Joint
Coping
Joints.

Fig. 129.

Mouldings.—Mouldings may be classified under two heads, Classic and Gothic. The Classic are those derived from those employed by the Greeks and the Romans Invariably the Roman mouldings are found to have their prototype in the Grecian examples, the chief difference being that the Greek are either segments of some of the conic curves or are struck freehand, while the Roman curves are all segments of circles (Figs. 130 to 138).

There are nine typical examples, as follows:

1. Fillet.—This is a narrow, flat projection, often used to divide individual mouldings or groups of mouldings in any composition; it is similar in both Greek and Roman work, as shown in Fig. 134.

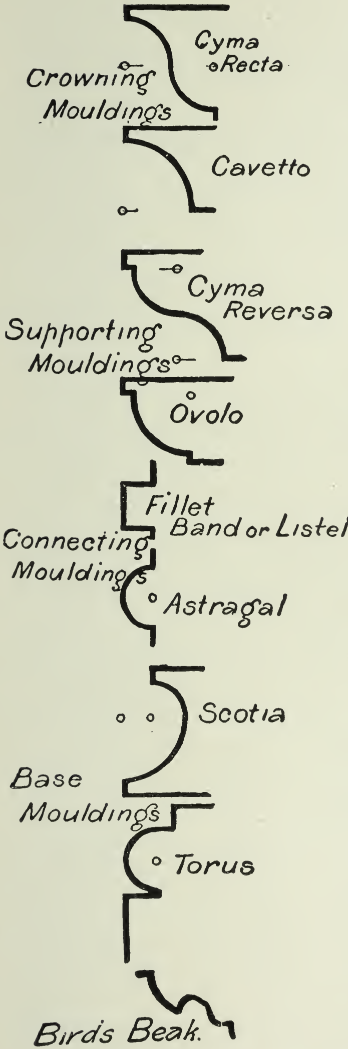
2. Astragal is a small semicircular moulding, as shown, often used in combinations of mouldings, but chiefly to mark the division between the shafts and caps of columns. This member is similar in Greek and Roman.

3. Cavetto.—The cavetto is a hollow moulding, consisting in the Greek of a quarter of an ellipse and in the Roman of a quadrant.

4. Ovolo.—This moulding in the Greek consists of a segment of an inclined ellipse, having a fillet at the top and bottom, and forming at the top a quirk. In Roman work it is a quarter circle, bounded at top and bottom by a fillet.

5. Cyma Recta.—This is a double curve, formed in the Greek of two quarter ellipses whose minor axes are in the same straight line and bounded top and bottom by a fillet. The Roman example is similar, but consisting of two quarter circles. This moulding has a concave portion of its surface above the convex, and is generally used as a crowning member.

6. Cyma Reversa, as its name implies, is the reverse of



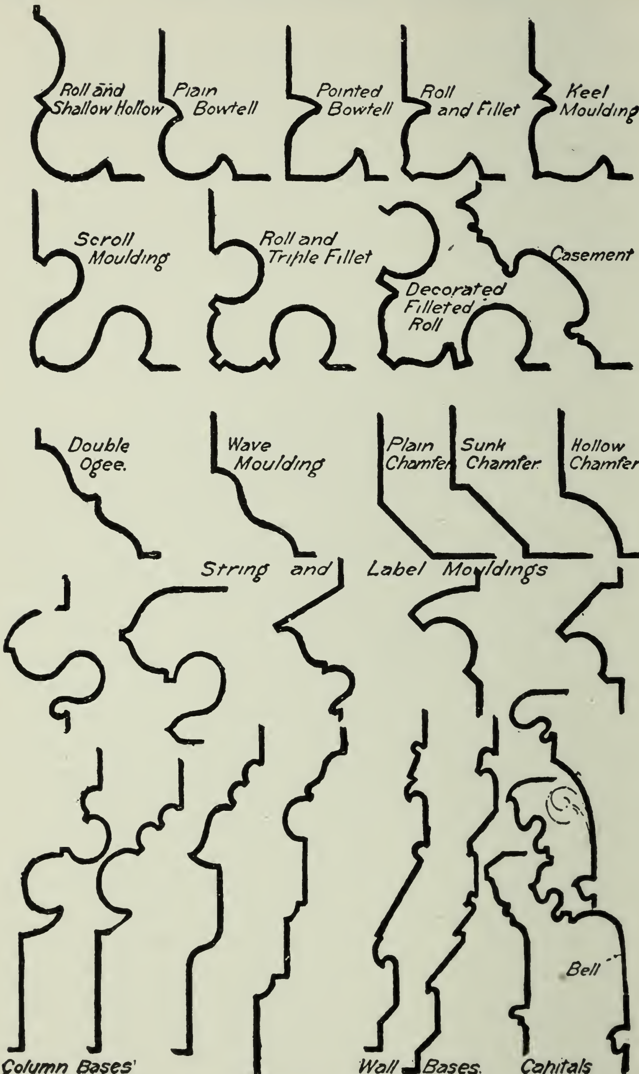
Figs. 130 to 138.

the preceding moulding, slightly modified in the Greek by having a quirk above, between the same and the fillet, and the hollow portion slightly more concave. The Roman is an exact reverse.

7. *Scotia.*—The scotia in the case of the Greek is formed of an inclined ellipse, having a fillet above and below. The Roman is struck from two centers on a common radial line.

8. *Torus.*—The torus is a base moulding, the Greek form being the reverse of the scotia. Many Greek examples are, however, similar to the Roman, consisting simply of a large semicircle with a quirk below and fillet above.

9. *Bird's Beak.* — This moulding only occurs in the Greek mouldings; it consists of a quarter ellipse, with the major axis horizontal, in the lower side of which a small hollow has



Types of Gothic Mouldings.

Figs. 139 to 165

been worked, and is used as a supporting moulding.

In the designing of groups of mouldings for cornices, strings, etc., reference should be made to the suitability of the forms for their intended position, and for this purpose they may be divided into base mouldings, connecting mouldings, supporting mouldings, and crowning mouldings. The base mouldings would include such mouldings as the torus, the scotia or the inverted cyma recta, and any combination of such mouldings that would tend to broaden the base and distribute the weight of the mass supported.

Connecting.—These include the fillet and the astragal.

Supporting.—The supporting mouldings include such members as the ovolo, bird's beak and the cyma reversa, mouldings that do not have their hollow members near their upper edge, and such as have their mass in a position to strengthen them, and are fitted to act as corbels. These mouldings are used to form the bed mouldings or lower parts of combinations, such as cornices which are divided into two parts, the bed mouldings and the crowning mouldings.

Crowning Mouldings are those mouldings which are not expected to carry anything above, such as the cyma recta and the cavetto, the top members of which are small and delicate.

The above ideas are not always rigidly adhered to, and successful departure from them is often made with good effect; but it is prudent to bear these principles in mind when designing any groups, for if too widely departed from, confusion ensues.

Gothic Mouldings.—Figs. 139 to 165 give a selection of the mouldings commonly used in the Gothic periods, combinations in archivolts, also for strings, wall bases, bases and capitals of columns.

SPECIFICATION CLAUSES

MATERIALS

STONE

1. The whole of the stone to be of the best description of its respective kind, and to be free from sand holes, vents, flaws, and all other defects. Should it be disapproved it shall be removed at once from the site.

2. Any stone which will not sustain a load under test of 2-in. cubes equal to..........lb. per sq. in. may be rejected and the contractor is to furnish to the architect, if demanded, fair cut cubes taken from any stone challenged by the architect, and the test of such cubes shall be considered a test for all the stone of a similar character.

3. The....................stone is to be obtained from the quarry of.................... to be equal in all respects to sample blocks deposited with the architect, and approved by him in writing.

NOTE.—This clause should be repeated for each different stone to be employed in the building, to prevent the substitution of an inferior material. In no case should an architect specify particular stone by a general trade name. In the case of sandstone for sills, hearths, etc., the following clause may be used.

4. The stone is to be of an approved quarry, and the contractor is to deposit samples of the stone he proposes using with the architect, and obtain his approval in writing before ordering same.

5. All cut stone work of every description, including window and door sills, caps, corbels, cornices, steps, railings, brackets, balcony floors, chimney caps, copings, fireplace lintels to be cut as per plans, details, etc., for the same, and to be delivered at the building properly fitted and with all necessary lewising and drilling for anchors by the stonecutter.

6. Any stone found at completion to be broken or defective is to be cut out and replaced by the contractor.

MATERIALS FOR OTHER TRADES

FOR "DRAINLAYER" (HOUSE DRAINAGE)

7. Provide good stone covers for air inlet chambers, 2 ft. 9 in. by 2 ft. 9 in. by 4 in. thick, finely tooled on top and edges, with rebated perforation for cast-iron hinged grating in frame.

8. Provide good stone covers 3 ft. by 3 ft. by 4 in. thick, for partially covering manholes, as shown on drawings, with circular perforation, 1 ft. 9 in. in diameter, for entrance.

9. Provide stone covers, 2 ft. by 2 ft. by 4 in. thick, for tops of lamphole shaft, terminating in roads or carriageways, with perforation the full diameter of the top of the pipe. The covers to be finely tooled on the top and edges, and to have 3 in. block letters "L. H." cut in on the surface.

10. Provide for inspection junctions stone covers, 18 in. by 18 in. by 3 in. thick, finely tooled on top and four edges to have 3-in. block letters "I. J." cut in on the surface.

11. Provide for the cleaning eyes stone covers, 18 in. by 18 in. by 3 in. thick, finely tooled on the top and four edges, to have 3-in. block letters "C. E." cut in on the surface.

FOR "MECHANICAL ENGINEER"

12. The cover for engine bed to be of..........stone, 16 in. thick, with chamfered edges, holed through in four places for holding down bolts, all as shown on drawings.

13. The coping for walls of flywheel race to be 9 in. by 6 in. ....stone boasted coping.

14. The flag cover for boiler sides and flues to be 3-in. hard ....stone flags with boasted overhanging edge.

15. The coping for blow-off pit to be 9 in. by 6 in........... stone boasted coping rebated for iron plates.

WORKMANSHIP—GENERAL WORK

16. All stone work to be set in best manner, every stone well bedded with complete full squeezed out joints in cement mortar, and all work in contact with brick to be plastered with similar cement to protect from stains, and all the brick backing of same to be set in similar cement mortar.

17. All stones to be well wetted before setting, and large stones to be set with a derrick. Rake out mortar joints when setting.

18. The joints between cut stone blocks in all columns or wherever any weight is brought on any cut stone work to be made with 5-lb. sheet lead worked back from the face 2 in., the center being cut out to allow space for settlement.

19. No angle miters will be allowed in any part of the work.

20. All window sills and all belts forming window sills to be in one stone each if desired by the architect.

21. The lines of all mouldings, curves, angles or miters to be worked to their true and proper forms, and all returns of miters of mouldings, washes or bevels to be worked on and out of the solid. The beds and joints of all stonework to be square with the face.

22. All rebates for frames to be cut in the stone joints according to plans and directions of the architects. All the windows or other finish of stone to be in size and form as shown on detail drawings, moulded, etc., according to the details of each part.

23. All stonework to be jointed as shown or directed.

24. Fix in all joints, where shown on details or as directed, copper dowels (provided by "coppersmith"), tailing equally into each stone, and run with oil cement. No iron dowels, galvanized or otherwise, will be allowed, and if brought on the job shall be returned immediately.

25. Carefully perform all cuttings and dowelings of holes for iron railings, crestings, bars, anchors, etc. Also all cutting for all galvanized iron, tin and lead flashing to the several roofs and wherever else required.

26. Chases to be left in all walls where shown on drawings, or wherever required for the running of steam, gas, and water pipes, or for any other purposes which may be found to be necessary after the work has been built.

Cut chases and break out holes for steam, water and gas pipes, or for any other purpose.

27. The front entrance to have ..in. by ..in.........stone rubbed top and front, and back-jointed step with sunk and moulded front, and with short returned sunk and moulded ends.

The tradesmen's entrance to have ..in. by ..in. good free stone, tooled top and front, and back-jointed step.

All steps to be kept up 2 in. above floor to allow for thickness of mat.

The doorways to..............to have..in. sound, free stone,

rubbed, and back-jointed both edges, thresholds the full widths of the walls.

All steps and thresholds to have mortises for dowels of door frames.

28. To be of..........stone 14 in. by 6 in., wrought, sunk, weathered, throated, and rubbed on all exposed parts, including the soffit of the projection, grooved for metal tongues, and set in mortar.

All to have proper stools for jambs.

29. Finish the parapet next..........with 14 in. by 6 in. suitable stone rubbed saddle-backed, double-moulded (to detail), and double-throated coping, with kneelers, springers, bonders, etc., of the sizes shown.

Finish the parapet over............with 13 in. by 3 in. suitable stone, tooled and weathered coping throated on both edges.

All copings to have lead-plugged joints.

Note.—Iron should not in any case be used as cramps. Should cramps be preferred to lead plugs, copper or gun metal should be used.

30. Carefully bed and dowel all cornices in cement mortar.

31. The heads to windows where shown to be stone to be of ....stone stop, moulded to detail of the sizes shown, and 6 in. longer each end than the width of the opening.

32. The staircase from ground floor to basement to have..in. by ..in. tooled all round threads, and ..in. by ..in. tooled all round risers.

The staircase from ground floor to..........to have ..in. by ..in. rubbed all round............stone spandril steps, splay rebated and splay back jointed with sunk and moulded fronts with solid square wall ends. The other ends to be returned and moulded to match fronts.

The bottom step to be solid with curtailed end as of the size shown.

The landings to be..in. thick, sunk and moulded on free edges to match steps with cement-plugged joints. Fill in between landing and steps below same with ..in. by ..in. splay rebate and splay back-jointed filling-in piece with fine rubbed joint.

All ends of steps and edges of landings next walls to be built in at least 4½ in.

33. Properly cut and pin, or build in the walls, all ends of steps, edges of landings, etc., requiring it.

34. Put 4 in. rough..........stone corbels under all overhanging chimney breasts.

35. Turn relieving arches of such span as may be directed in walls over weak spots in the foundations or over openings.

36. Put under ends of rolled joists up to ..in. by ..in., 14 in. by 9 in. by 3 in., under ends of larger rolled joists 14 in. by 14 in. by 4 in., and under ends of riveted girders 18 in. by 14 in. by 6 in. ....stone templates, finely tooled for iron, and with tooled edges where exposed.

37. The columns and stanchions to have 21 in. by 21 in. by 6 in. ....stone bases finely tooled for iron and mortised for lugs.

Note.—The columns and stanchions to be slightly wedged up with steel wedges, and run in with neat cement.

38. Chimney stacks to be worked according to detail drawings and properly cramped as directed. The top stone of chimneys where possible to be in one stone with holes cut through for flues.

39. All rolled joists and girders carrying walls to have 3 in. stone tooled covers with coped edges bedded in cement.

All riveted girders to have bed of cement on top of same to cover rivet heads.

40. Put 3 in. rough stone flags bedded and jointed in cement as cover to dry area.

41. The curb to area outside............to be 9 in. by 6 in. ....stone tooled all round with cement-plugged joints.

The curb to area outside..........to be similar, but rebated for pavement lights.

42. The kitchen and scullery fireplaces to have 2½-in. stone rubbed front and back hearths.

The remaining fireplaces where stone hearths are shown to have 2 in.........stone rubbed front and back hearths.

All to be 12 in. longer than the width of opening and 18 in. projection, except to kitchen, which is to be 24 in. projection.

43. The kitchen chimneypiece to have 7½ in by 2 in......... stone rubbed jambs, and 9 in. by 2 in..........stone mantel and shelf. The shelf to project 6 in.........each end beyond mantel, with rounded corners, and to be supported on 12 in. by 6 in. by 2 in. rubbed and moulded stone corbels cut and pinned in wall.

44. Provide and fix..........stone rubbed and dished sink in

scullery 3 ft. by 1 ft. 8 in. by 5 in., all in clear, the bottom to fall and holed for grating.

NOTE.—Glazed stoneware sinks are generally preferable to stone, except in special cases.

45. Provide and fix as shown a 4 in. chamfered and holed top to copper, to be in one slab of rubbed..........stone.

46. Cut all grooves and rebates as may be required for glazing, etc., up the jambs and mullions, and in the tracery, and well point upon both sides with coarse putty.

47. Form rebates for iron casement frames, and provide plugs and holes in stone to each.

48. Mortise steps, sills, etc., for tenons of door frame shoes, and run in the tenons with lead.

49. Each bell pull at entrances to be let into a stone 9 in. by 9 in. by 9 in., set in cement and sand, sunk for pull, and mortised for wire.

50. Cut proper mortises in the stone for the ends of all saddle bars, stanchions, etc., and run in with cement; properly let in and run with lead all double fangs of hinges, staples, catches, sockets, etc., as may be required.

51. All works intended for carving to be prepared by the mason, and all boasting necessary to be done by him, great care being taken to leave sufficient stuff to give the carver plenty of scope. The carving to be done by professional carvers approved of by the architects, and according to detail drawings to be furnished. Carving to be done either on the ground or in position after the building is up, as directed by the architects.

52. Provide and allow for selecting a specially jointed foundation stone and for cutting inscription on same of about........ letters 2 in. high, and cutting a cavity in same, and provide an air-tight solid copper box to hold papers, etc., to be deposited in same, and allow for extra labor and materials in setting stone with usual ceremonies. Also provide and allow for clearing up the parts of the building near the stone on the day appointed by the building owner, and making the premises clear and safe and available for the usual assembly and allow for interruption of such work as necessary.

53. Thoroughly clean down all work at completion and clean out and point all joints in cement, tinted to match stone, well tucked into joints and finish with a neat flat surface.

54. Lime whiten all exterior wall surfaces, mouldings, etc.

SPECIAL CLAUSES FOR A CHURCH

LABORERS

55. The whole of the stone to be of the best description of its respective kind, to the architect's approval; to be free from sand holes, vents and all other defects; to be worked to lie on its natural bed when set, and to be bedded and jointed, except where otherwise described, in mortar (or putty), with wide (or fine) joints, which are intended to show.

All the stone is to be worked on the site, and particular care is to be taken to preserve all the joints of the stonework from the irregular appearance which is caused by the arrises being broken before the stones are set. No work thus injured will be allowed to be used, and no patching will be allowed. The stonework to be so truly worked as not to require any cleaning off beyond washing.

56. All the dressings (unless otherwise described) to be finished off with a fine drag (or a chiselled face or rubbed) in a manner to be approved by the architect, and to be bonded and fixed in the most substantial manner.

57. The vertical joints of sills, parapets, cornices, and all joints in tracery of windows, in vaulting ribs and chimney caps, are to have double cement plugs and mortises for same, or double V-grooved joints run with cement as may be necessary.

58. The mullions, copings, jamb shafts, pinnacles, and such are to have 1 in. or 1¼ in cube slate dowels (as required) to every stone in the bed, run with cement, with proper mortises for the same

DRESSINGS

59. The external dressings of windows and doorways, also the copings, strings, gable crosses, weather courses, weatherings, etc., etc., are to be executed in........... All external angles of dressed stonework to be worked in the solid.

60. Provide and fix hinge and lock stones as shown on the drawings and as required. (It is sometimes advisable to make these stones of a harder material than the dressings.)

61. The internal dressings, unless otherwise described, are to be of.........., finished with finely-rubbed faces.

62. All internal angles of dressed stonework to be worked in the solid.

63. The detached piers and springers over same are to be exe-

cuted in..........stone. Internal detached shafts to be of ....stone (or marble, etc., etc.) as required, the whole to have circular, finely-dragged faces, or to be chiseled (or rubbed), the top and bottom beds to have mortises run with cement, and the intermediate joints to have light copper cramps as may be directed.

ASHLAR

64. The internal facing throughout to be of........stone ashlar. The external facing is to be of........stone ashlar. The courses are to be of various heights (averaging 6 in. on the bed) from 4 in. to 10 in., and to line generally with the beds of dressed stonework. They must also be properly bedded and bonded into the body of the walls. Each stone must be set in mortar, cut, and properly fitted up to the dressings, arches, etc., and be finished with a finely-dragged or chiseled face.

VAULTING

65. The springers of the vaulting must be worked on the solid as shown on detail drawings; they and the wall ribs are to be built into the walls as the work proceeds, but those portions of the groin ribs which are fully developed on the springers, as well as all the filling in, will have to be set after the roof is up and covered in. The contractor is to allow for any extra scaffolding, labor, etc., that may consequently be required.

66. The cells of vaulting are to be filled in with........stone 4 in. thick in narrow courses built in mortar, the soffits to be slightly arched or cambered, and the surface to be finely dragged or chiseled to match the internal ashlaring, etc.; it is to be cleaned off and the joints struck as the work proceeds, to be properly cut up to the stone ribs, and to have all necessary centering or laths that may be required for the support of the cells whilst building.

SUNDRIES

67. The gable crosses to be of........stone worked according to the drawings, and fixed with 3 in. by 1 in. by 1 in. slate dowels run with cement.

68. The masonry in all towers to be built with special care with large flat stones, carefully bedded, each stone to break joint over the center of the stone below. Not more than........stones to be placed in the width of the wall set in mortar and grouted as described for the other portions of the work. All joints to be

true and close, filling in the walls with spalls will not be allowed.

69. The tops of the turret and chimney stack are to be built as shown on the drawings, the top and cap stones of turrets and the top stone of chimney to be solid and perforated for the flues and finial rods as required.

70. A weather course to be fixed round chimney stack, also on ...., all with solid springers, apex, and bond stones about 4 ft. apart. (Some prefer to work these entirely on the solid.)

71. The chimney-piece in vestry to be formed in............ stone, as shown by the detail drawing, and to be properly doweled together and tied with copper cramps into the walls. The fender to be of stone, 3½ by 3½ in., rubbed and moulded, with dowels and cement plugs as required, and to have circular corners as shown by the drawings.

72. The seats in sedilia, the bottom of piscina, etc., to be also of..........stone, all of the widths and thicknesses shown.

FLOORS AND STEPS

73. The altar stone to be a 6 in. rubbed..........slab in one stone, and of the size of the altar as shown.

74. The steps within the chancel and at the entrances thereto are to be of the best selected..........stone, rubbed top and front and back-jointed; to be in long lengths with fine joints and double cement plugs in same, and of the sizes shown; all to be bedded hollow on brickwork. Similar steps to be fixed........

75. The heating vault and.........to have 2½ in. tooled...... paving in mortar.

CARVING

76. Provide models to the approbation of the architect, made by an artist, for the whole of the carving; the whole to be made to a scale of 3 in. to 1 ft.

77. Perform in an artistic manner to the satisfaction of the architect, the carving of the pendants, battlements, foliated arches, finials, crests, small domes, and of every other part of the building.

Note.—It is more often the custom in the best work to insert a provision for the carving of a building, such sum to include cost of making necessary models.

78. Clean down the masonry work and generally leave the

whole perfect and complete, omitting no material or workmanship either described or implied by the drawings and this specification, or that is necessary to render the whole complete in every respect.

NOTE.—Many architects will not allow any cleaning down. There is little doubt but that the custom is injurious to some stones, as it removes the natural case-hardened weather-face.

SPECIAL CLAUSES FOR A BUILDING IN A STONE DISTRICT

79. The stone for wallings, footings, and dressings generally to be obtained from . . . . quarry. (If the quarry belongs to the building owner, insert the following:—No royalty will be charged, but the contractor will have to quarry the stone and convey it to the building. The quarry to be left in good order at completion.) Stone for sills, mullions, transoms, string courses, cornices, copings, weatherings, and other exposed positions to be obtained from the . . . . quarry belonging to Mr . . . . The whole of the stone to be set so as to lie on its natural quarry bed.

80. Build the footings with large flat-bedded rubble walling stones, specially selected for the purpose, in mortar thoroughly bonded, bedded perfectly level, filled in solidly, and flushed up with mortar.

Properly lay up the cellar walls with good hard flat building stone . . . . in. thick, firm built and well bonded with a thorough stone at least in every yard super., laid in clean lime and cement mortar in parts of one of cement and two of lime, laid by and full to a line on both faces and flush and point at completion. Lay down in like manner substantial foundations under all chimneys, piers, and exterior steps, and all clear of frost. Leave all openings in walls for drain, gas and water pipes, as directed or as shown on plans.

81. The walls to be carried up in roughly-chiseled ashlar in mortar, to be thoroughly bonded and packed, and well flushed up with mortar and small stones.

82. The inside face to be carried up true and even in brickwork to receive plaster ($4\frac{1}{2}$ in. lining properly bonded with headers into wall).

83. The outside surface to be executed in roughly-chiseled

ashlar (the local rubble stone in horizontal random courses to average 7 in. on bed with one bond stone at least to every yd. super., the beds to be roughly hammer dressed, and the surface to be chopped to remove any great irregularity as shall be directed, the courses to vary from (3 in.) to (7 in.) high, and in stones between (14 in.) and (24 in.) long with occasional large square stone). The pointing to be done as the work is carried up by passing the point of the trowel over the joint, so that the mortar shall in no case project over any portion of the stones, and the joints to be slightly weathered.

84. The quoins to be got out of the best local weather stone, to be long each way on the bed, and well bonded into rubble walling, the angles to be truly formed, and the surface to be axed with irregular upright and diagonal strokes as shall be approved. or, if of rubble, "the quoins to be executed in selected large stones."

85. Provide for covering the tops of walls with asphalted felt if they should be uncovered during frost or very wet weather.

Plates I, II, III, IV. STAIRCASES.

The *tread* of a step is the upper or horizontal surface, and the *riser* is the front vertical face or upright portion of the step. The *soffit* is the under surface, and in spandrel steps is inclined from the horizontal. The *nosing* is the front edge of the tread and riser, and is either square or moulded.

Flyers are straight steps with parallel edges.

Winders are steps with converging edges on tread, and parallel edges on riser, and generally a twisting surface on soffit.

For general purposes, the tread of a step should not be more than twelve inches, nor less than nine inches, and the rise of a step should not be more than seven inches, nor less than five and a half inches.

The proportion usually adopted, is any two numbers between the above sizes which, multiplied together, produce sixty-six: namely, a twelve-inch tread by a five and a half-inch rise equals sixty-six, or $11 \times 6 = 66$, and again $11\frac{1}{2} \times 5\frac{3}{4} = 66$. This, however, may be slightly modified—as, for instance, a ten-inch tread and a six and a half-inch rise equals sixty-five—but the rule may be relied upon as safe in working to.

A staircase easy of ascent, and in other respects desirable, is one in which all the steps are flyers, and having quarter or half-space landings.

Long straight flights with more than twelve steps before reaching a landing should be avoided.

Where there is a deficiency of room or space, winders

have to be introduced; and these, if properly arranged, need not interfere with the ease of the ascent.

In setting out, for the purpose of making the moulds, the first point to be considered (the plan being satisfactory) is the width of the tread and the rise of the steps; these are best obtained by measuring the length and width of the well-hole, and the height from floor to floor, from the actual work if practicable, and then dividing out the dimensions thus obtained into the number of steps on deal rods, or it may be also found by calculation. The height rod is called the storey rod, and this and the other rods are afterwards used in the fixing of the stairs.

Fig. 1. To set out a SPANDREL STEP MOULD.

Draw a line *F B*, and line *B C* at right angles to same, and on *F B* set off *A B* the width of tread, and on *B C* the height of rise. From *A* to *C* draw a diagonal line cutting tread and rise at their extremities, and draw parallel to it line *E D* for soffit, of a sufficient depth proportioned to the strength of the stone, which in this example is put at two inches. For the back rebate, set off from *A* to *F* one and a quarter inches, and from *F* draw line square with soffit to *E;* for the front rebate draw line from *C* to *G* square with the rise and set off one and a quarter inches, and from *G* draw line square with soffit to *D,* thus forming a birdsmouth, the exact reverse of the back rebate.

Allow one-twelfth of an inch for joint, which cut off from the mould as shown by double line at *C G D*.

A moulding or astragal nosing is added on to front of riser when necessary.

Fig. 2. Shows plan of a stair generally considered to be a good type.

STAIRS

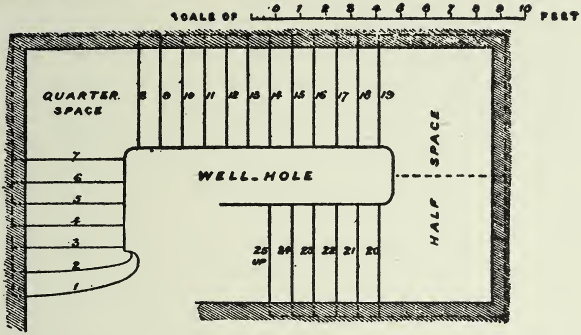
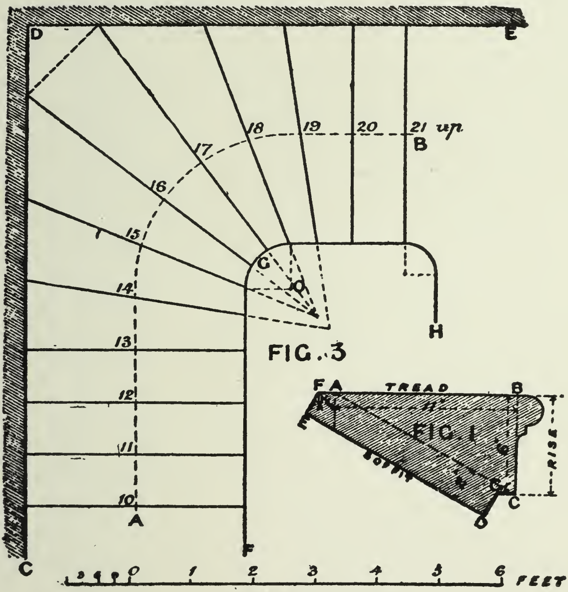


FIG. 2



SCALE TO FIG. 3.

It starts with two curtail steps and four flyers reaching a quarter-space landing, then eleven more flyers, reaching a half-space landing, and five flyers to the top landing.

The setting out of this requires no explanation.

Fig. 3. Shows part plan of stair with winders.

Fig. 4. Is a development of the plan of stair shown in Fig. 3.

The stairs should be set out to full size, and on a large board or platform, and it may be here noted that the riser lines only are essential to the setting out, both on plan and section, the moulded nosing being seldom shown.

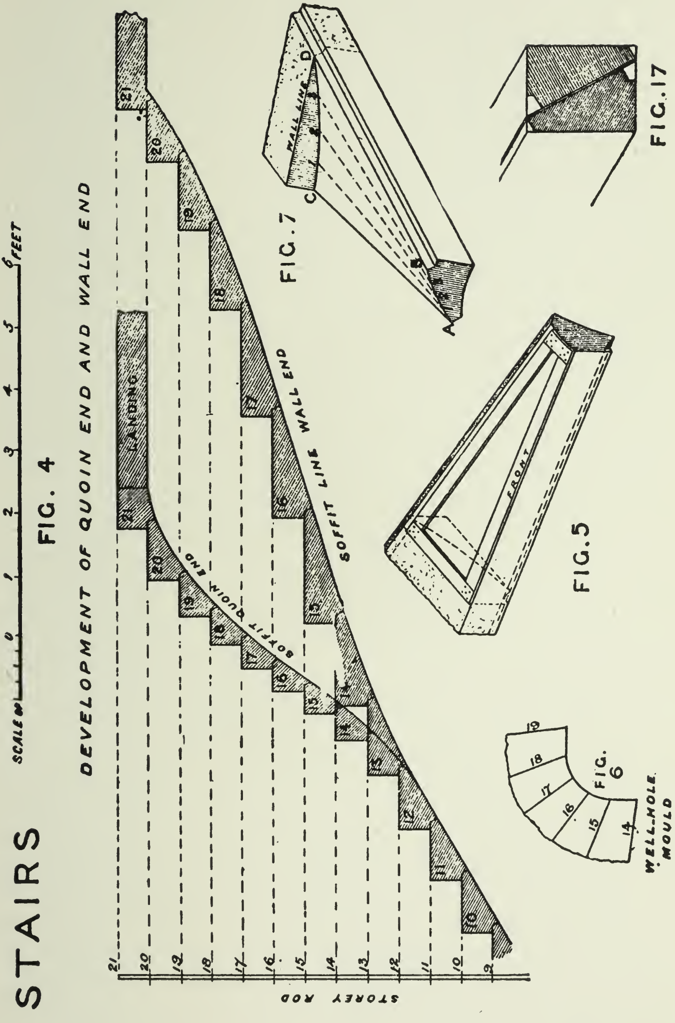
Begin with the plan and draw the wall lines *C D E*, and lines *F G H* for the quoin ends, draw centre line *A B*, and on this line from No. 13 to 20 divide out the winders equal to the width of tread of the flyers, dividing the quoin ends into the same number of parts.

These need not be equal in size, and the better result will be obtained if the ends are a little graduated from the flyers to the angle winder each way, in order to get a good tread and an easy line to the soffit and handrail.

The winders will not radiate from the center of quadrant *O*, but at a distance outside of it, as shown.

Another method is to draw the development of quoin end, and adjust the ends of steps upon this, until a good line for soffit is obtained, the riser lines are then transferred to plan.

To set up the development for quoin ends, draw parallel lines on board for the rise as given by storey rod, and begin at bottom by drawing No. 10 step, and then No. 11 and No. 12 steps. No. 13 is the first winder. Set off the exact size from riser to riser on plan and draw on board, proceeding in the same manner with No. 14. Nos.


STAIRS
FIG. 4
DEVELOPMENT OF QUOIN END AND WALL END
SCALE OF FEET
LANDING
SOFFIT QUOIN END
SOFFIT LINE WALL END
STOREY ROD
WALL LINE
FIG. 7
FRONT
FIG. 5
FIG. 17
FIG. 6
WELL-HOLE MOULD

15, 16, and 17 are segmental on plan. Set off the developed size of each respectively, following on with Nos. 18, 19, &c., till each is drawn, so that the distance from riser of No. 10 to riser of landing No. 21 equals the distance of quoin ends on plan, when unfolded or stretched out in a straight line.

For the development of the wall end, set out similarly to the preceding by taking the distance of each winder on the wall line of plan, and setting up the same on board. No. 16 is taken across the corner and not into the angle; with this exception the wall end is stretched out in a straight line.

The soffit has now to be considered. Begin by drawing an easy curved line, taking up with soffit of flyer No. 11 and finishing with soffit of landing No. 21, keeping the rebates about the same size as the ordinary steps; this it is not always possible to do, but the size of rebate is not of so much importance as that of having a good soffit line. The rebates to winders are in every instance of the same square section as the flyers, but in some cases may be less in depth or greater, according as the soffit line cuts through them. A small reverse should be made from the development for guidance in working each.

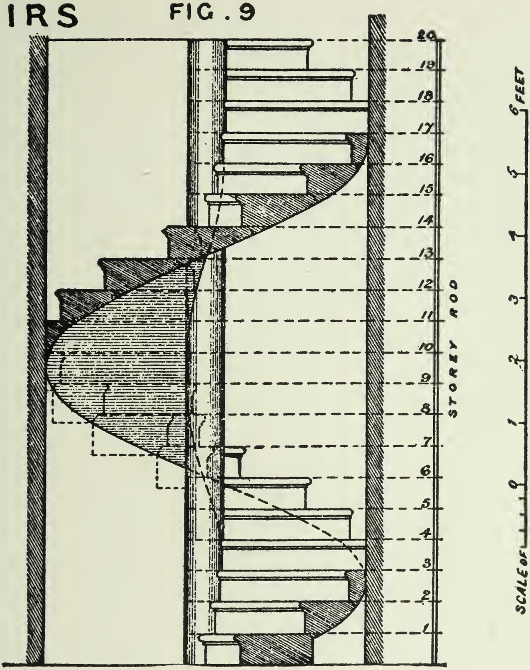
For drawing the soffit a flexible lath or rod is used, by means of which an easy and graceful line is obtained.

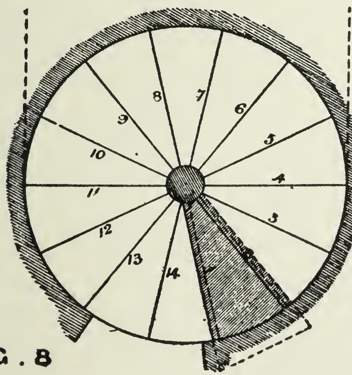
Fig. 5. The bed moulds for winders are made of deal laths about two inches wide by half an inch thick, nailed together as shown in sketch. The mould is scribed on the tread of the stone to be worked, allowance being made for the back rebate, and also for the tailing into wall, both of these dimensions being figured on the mould.

Fig. 6. Shows a well-hole mould, usually made of sheet zinc, used for guidance in drawing the segmental quoin ends.

STAIRS

FIG. 9





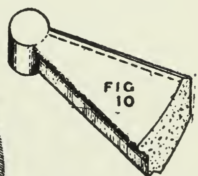


FIG. 10

FIG. 8

Fig. 7. Shows sketch of soffit of winder.

The working of the winder is plain straightforward work with the exception of the soffit, which is a twisted or warped surface.

Cut in draft as *A B* on quoin end and sink draft to templet at wall end as *C D*. Point off superfluous waste and divide drafts *A B* on quoin end, and *C D* at wall end, into four equal parts, as 1, 2, 3; work straight drafts from 1 to 1, 2 to 2, and 3 to 3; these are again to be subdivided and straight drafts worked to corresponding divisions at each end, until the whole soffit is finished to a true winding surface.

The square seating at wall end is left on for a good fixing into wall.

A winding stair with moulded nosing is worked in precisely the same manner as the foregoing, the only difference being in the nosing, the projection of which is an addition to the plain riser, the riser lines, rebates and soffits being in every case identical.

A point which should not be lost sight of in setting out stairs, is to see that sufficient head room is allowed; this should not be less than six feet six inches from nose of steps to soffit of flight over,—that is to say, the soffit line of flight over should not cut below an arc described by a radius of six feet six inches, taken from the nose of either of the steps beneath.

Fig. 8. Shows the plan of a winding staircase in a circular well, supported by a solid newel in the center, the newel being worked on each step.

Fig. 9. Is a sectional elevation of the winding staircase shown in Fig. 8.

It may be known to most of our readers, that if a piece of paper of the shape of a right-angled triangle be

STAIRS

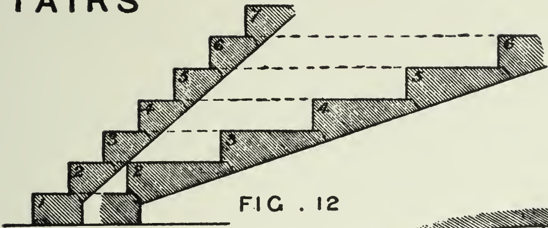
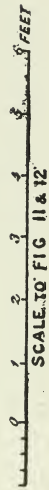


FIG. 12



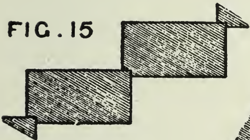


FIG. 15

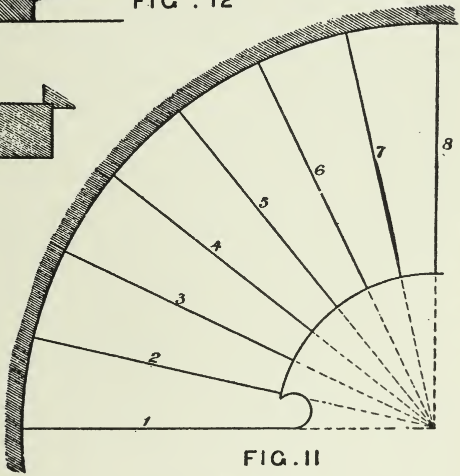


FIG. 11

FIG. 13

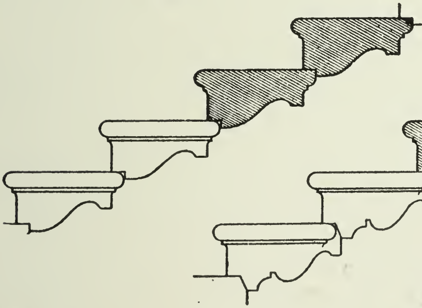


FIG. 14

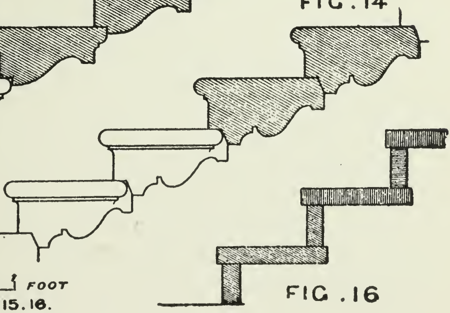


FIG. 16

SCALE TO FIG. 13.14.15.16.

wound round a cylinder, the hypotenuse (or long side of the triangle) will generate a curve winding round the cylinder in the form of a spiral. This curve is called the helix.

The soffit line of the stairs winding round the well, and line winding round the newel, is the helix, and the soffit contained between these lines forms a true helical plane; the development therefore of each end of the step is a straight line on the soffit, so that no setting up on section is required. The plan must be laid down on the board full size, the treads being divided out equally, and each step being similar and alike, one mould will do for the whole. The starting step is not generally worked on the soffit, but is kept solid.

The hatched line on Fig. 8 shows the extreme size of the bed mould of each winder.

The method of working the soffits will be similar to that described in Fig. 7.

Fig. 10. Shows a sketch of one of the winders, the newel forming a portion of each.

Fig. 11. Shows part plan of a circular stair, having an open newel or central well; this stair, like the preceding Figs. 8 and 9, is an example of the helix, the soffit being a helical plane.

Fig. 12. Is development of part of the circular stair of Fig. 11, showing quoin and wall end, the lines of soffit to each being straight.

The student who has worked out the previous examples of stairs will not, it is presumed, require any further instruction on the setting out and working.

Figs. 13 and 14 are elevations of quoin ends, and sections of two forms of bracketed stairs suitable for good buildings, such as hotels, mansions, clubs, &c.

Fig. 15. Is a section of solid square steps, suitable for warehouses, workshops, &c., where great strength is required.

Fig. 16. Shows sections of a simple form of steps, consisting of treads and risers in separate pieces, worked out of two inch or two and a half-inch stuff. These are chiefly used for back stairs, area steps, &c., and are inexpensive in construction.

Fig. 17. Shows method of sawing spandrel steps, one out of the other, so as to economize stone.

The treads of winders are also sawn in a similar manner.

Plates V, VI, VII, VIII. CIRCULAR WORK (RAMP AND TWIST).

Fig. 1. Shows plan of part of a Terrace Stair, with Balustrade following the inclination or rake of steps. The balustrade being circular on plan, it necessitates a certain amount of twist in its working.

[The method here adopted is not, perhaps, the most economical as regards material; but it is comprehensible, and more true in form when worked than with a complication of moulds and bevels, and the material is more than saved in the labor of working.]

Begin by laying down the plan full size on a large board or platform, carefully dividing the space for balusters equally.

Fig. 2. Set up the elevation to developed line of convex or outside face of plinth—that is to say, the line *A B C* on plan (Fig. 1), when stretched out or unfolded in a straight line, is equal to or of the same length as the horizontal line *A B C*. The line of inclination will be a helical line, as the steps are of equal tread and rise; therefore the plinth starts with a straight line parallel to the nose of steps.

On elevation set off the joints (convenient to the size of stone) for the plinth and capping at right angles to the line of rake.

Fig. 3. Set up the elevation to developed line of concave or inside face of plinth, and set off the joints which are to coincide with the outside joints. To obtain these, transfer the points from the elevation (Fig. 2) of out-

BALUSTRADE RAMP & TWIST

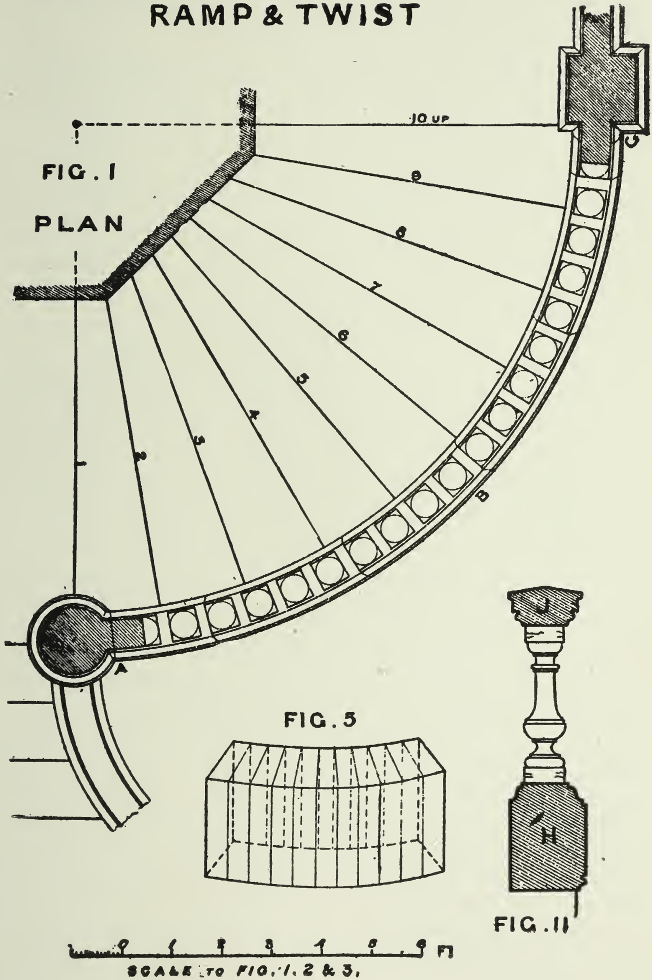


FIG. 5

FIG. 11

side face to the plan (Fig. 1), and produce the joint lines through to inside face by the lines radiating from centre, and re-transfer to the inside elevation.

The method of drawing the section of steps is shown by the dotted lines and the notation, this being similar to the plan.

For the purpose of illustrating the making of the moulds and the working of the stones a plinth block and length of capping are taken, as shown by hatched lines on Figs. 2 and 3. The details are given to a larger scale.

To work the Plinth Block.

The block of stone required to work the plinth block will be rectangular in shape, of the extreme length of the bed mould; and the width will be equal to the distance across the chord line, and the height will be that of the face moulds.

Fig. 4. *A* Shows bed mould of the plinth.
B Shows face mould of convex or outside face.
C Shows face mould of concave or inside face.

Begin by working the bottom bed to a true plane; then work the top bed parallel to it as a surface of operation, and taken to the height of the face mould. Scribe the bed mould in on each bed, care being taken to bone the points through so that the moulds are perfectly out of twist; proceed to work the concave and convex surfaces. For guidance in working this to a true form radiating lines are marked on the beds taken from the mould, and the straight edge is applied on the face to drafts coinciding with these. At this stage the stone is a true segment of a hollow cylinder, as shown in Fig. 5. Now apply face mould *B* (Fig. 4), to convex face, and face mould *C*

BALUSTRADE
RAMP & TWIST

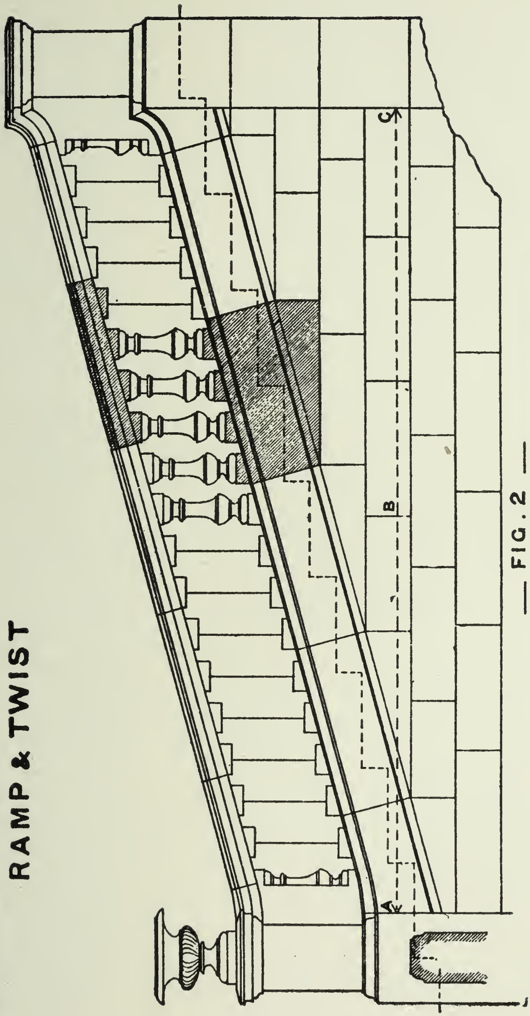


FIG. 2
DEVELOPMENT OF OUTSIDE ELEVATION

SCALE OF 0 1 2 3 4 5 6 FT

(Fig. 4), to concave face, and scribe them in to their respective shapes; work the joints through, and scribe in the section mould *H* (Fig. 11).

The top bed, or surface of operation, is now done with, except at the high corner which forms the bed of the baluster seating. Point off the superfluous waste down to the top of the other baluster seatings, and clean through the beds and sides of these from outside to inside face, as shown by sketch Fig. 6.

Next gauge the distance taken from the bed or section mould of seating of baluster to the convex and concave faces, and work the same, thus completing the baluster plinths.

For guidance in working the ogee raking mouldings, a bending strip or thin lath, and one or two small reverses cut to section of moulding, will be all that is required, and the stone is finished as in sketch (Fig. 7).

Each of the other plinth stones are worked similarly.

To work the Length of Capping.

Fig. 8. *D* Shows bed mould of the capping.
E Shows face mould of convex face.
F Shows face mould of concave face.

This stone is worked in precisely the same manner as the plinth—namely, by working first a segment of a cylinder to the shape of the bed mould and to the height of the face mould, as in sketch (Fig. 5). Then apply face moulds *E* and *F* respectively to the convex and concave faces, and scribe them in. Work off the joints, and scribe in section mould *J* (Fig. 11); next point off the superfluous waste, and work the baluster seatings as before described. Trammel lines for raking mouldings and work

BALUSTRADE

RAMP & TWIST

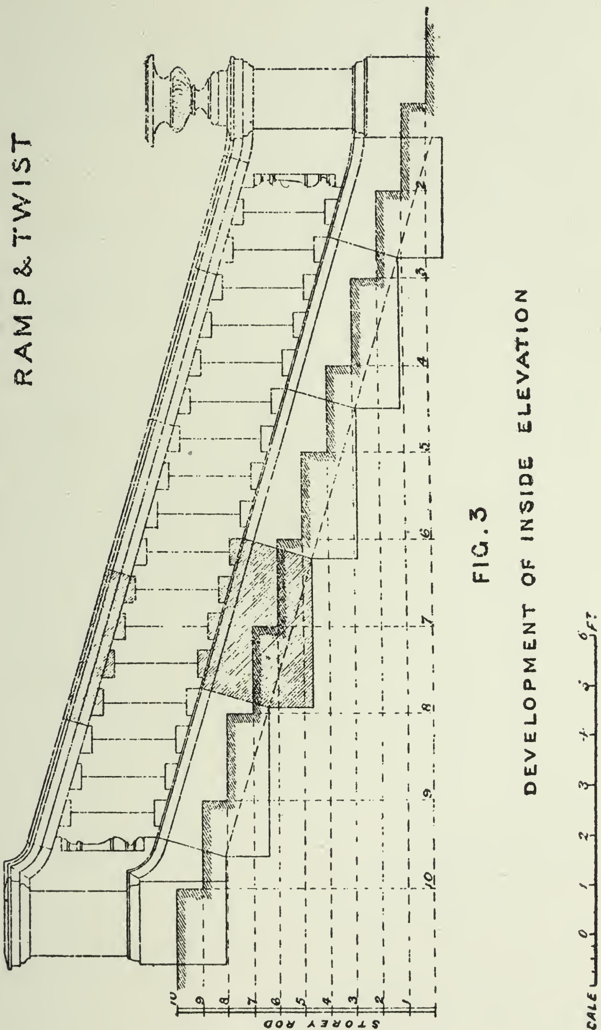


FIG. 3

DEVELOPMENT OF INSIDE ELEVATION

them through, assisted by a bending strip and reverses, and finish by working off the saddle-back weathering.

The small seating or plinth of baluster is worked on the plinth and the capping, in order that a level bed may be obtained in fixing the baluster.

Each of the other lengths of capping are worked in a similar manner to the foregoing.

Fig. 10. Is sketch of length of capping finished; this is slightly tilted up, so as to show the baluster plinths.

Fig. 11. Shows section of the plinth, capping, and baluster.

FIG. 4

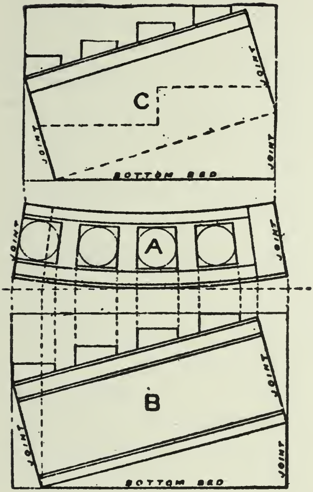
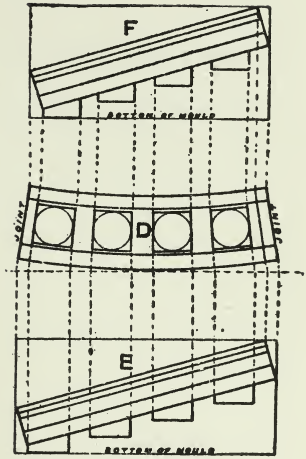


FIG. 8



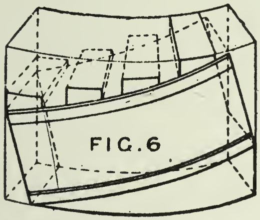
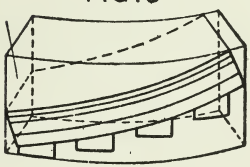


FIG. 6

FIG. 9



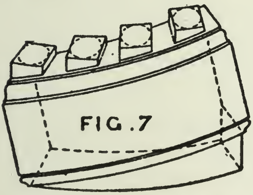
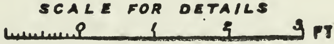


FIG. 7

SKETCH OF FINISHED PLINTH

FIG. 10

SCALE FOR DETAILS



Plates IX, X, XI. CYLINDRICAL VAULTING.

To obtain the Profiles or Curvature of a Groin.

Fig. 1. Let *A B C D* be a rectangular plan, its vault to be intersected by two semi-cylinders.

Bisect the line *H J,* and with *F* as a centre, describe the semi-circle *G H J* (the given section), which divide into any number of equal parts in this example 12, and project ordinates 1 2 3 4 5, &c., through the springing line *H F J* on to the diagonal line *A E D* as 1′ 2′ 3′ 4′ 5′, &c. Erect ordinates perpendicular to the diagonal, and make them equal in height to those of semi-circle *G H J,* and through the points of intersection draw the semi-ellipse, which is the curve of the groin.

The outer profile *K L M* is obtained in the same manner, namely, by projecting ordinates from the diagonal, and making them of equal height to those of semi-circle, and tracing semi-elliptic curve through the points of intersection.

These profiles may also be obtained by means of an elliptic trammel, taking *A D* and *K L* respectively as the major axes, and *E N* and *M O* as the minor axes, and drawing semi-ellipses by a continuous curve.

To obtain the Profiles for the Annular Groin.

Fig. 2. Let *A B C D* be the given plan.

Produce *A C* and *B D* until they meet in the point *X,* which is the centre of the radiating vault; bisect the line *A C* and *B D* at *E* and *G,* and describe the two semi-circles *A J C* and *B D H* the given section; divide the

FIG. 1

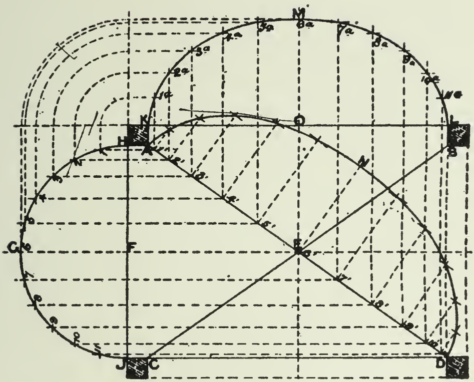
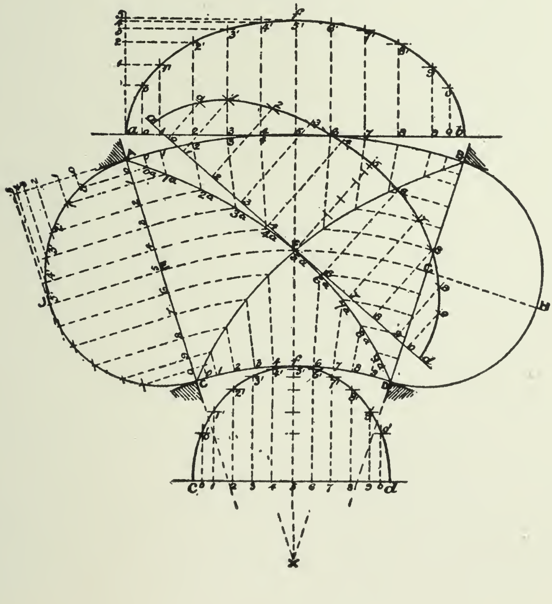


FIG. 2



diameter of either semi-circle as *A C* into any number of equal parts—in this example 10—the last division from 1 to *A* and 9 to *C* may be again divided as at *O,* and erect ordinates as *O* 1 2 3 4 5, &c., cutting the semi-circle at O' $1'$ $2'$ $3'$ $4'$ $5'$, &c.; at the centre *X,* with radius *O* 1 2 3 4 5, &c., on the diameter *A C,* describe concentric arcs to the diameter *B D.* Divide the segmental line *A* 5 *B* into the same number of equal parts as the diameter *A C,* as *O* 1 2 3 4 5, &c., and from these points draw radiating lines from centre *X,* intersecting the above arcs at O^a 1^a 2^a 3^a 4^a 5^a, &c., and through the points of intersection draw the curve, giving the plan of groins *A F D* and *C F B.*

To describe the outer and inner profiles, develop segmental line *A* 5 *B* as right line *a b,* and *C f D* as right line *c d,* and transfer the divisions *O* 1 2 3 4 5, &c.; erect ordinates as O' $1'$ $2'$ $3'$ $4'$ $5'$, &c., equal in height to those of the semi-circle *A J C* and through the points O' $1'$ $2'$ $3'$ $4'$ $5'$, &c., draw the curve which gives the true sections.

To find the profile on the diagonals *A F D* and *C F B,* develop line *A F D* as right line *a F d,* and transfer divisions $O^a 1^a 2^a 3^a 4^a 5^a$, &c., on the same, erect ordinates, and make them equal in height to those of the semi-circle *A J C;* through the points of intersection draw the curve, giving the true section at the mitre of groins, when bent or worked, so as to stand on the curve *A F D* on the plan.

To construct a RECTANGULAR VAULT, intersected by two semi-cylinders, crossing each other at right angles, and of equal height, each course of Stone being level and parallel to the axes of the Cylinders.

Fig. 3. Let *A B C D* be the springing of the groins, *A E D* and *C E B* plan of the groins or intersection of cylindric surfaces, *F H G* is a section of the soffit or in-

VAULTING — CYLINDRICAL

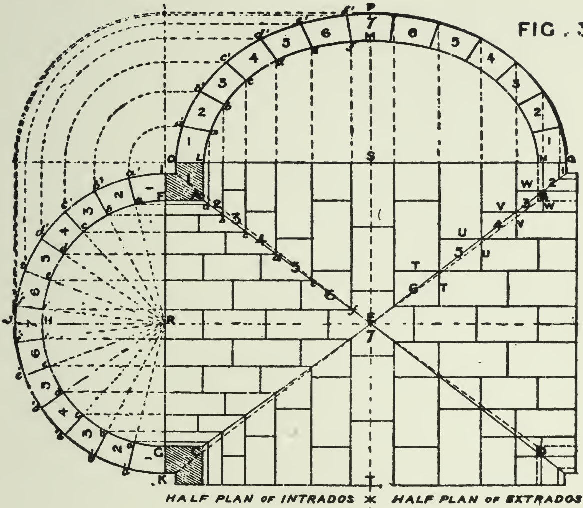


FIG. 3

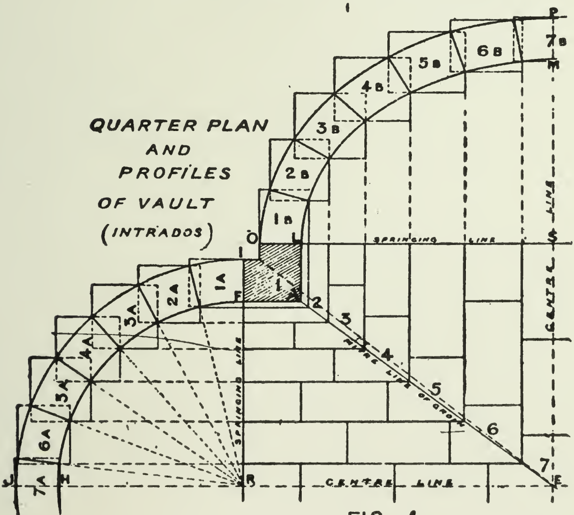


FIG. 4

trados whose profile is a semi-circle, and *I K J* a section of the outside or extrados, both of which are concentric semi-circles. The form of this section determines the shape of the groin and outer profile. *L M N* and *O P Q* are sections respectively of the intrados and extrados of the semi-elliptic profile, the curves of which are found by the method described in Fig. 1.

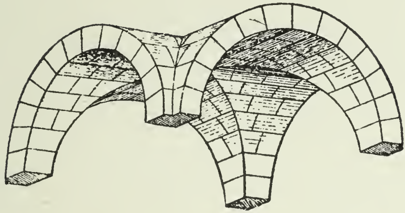
To obtain the joints, divide the semi-circle *I J K* into any unequal number of equal parts (convenient to the size of the stones), in this example 13, and draw the arch points radiating from the centre *R* as *a′ b′ c′ d′ e′ f′*, &c. From the joints on the soffit, as *a b c d e f*, &c., project lines on to the plan, cutting the diagonal line *A E—C E* at *a b c d e f*, &c.; and, from these points of intersection, project lines on to the semi-ellipse *L M N* for intrados, and project points from the extrados *I J*, to the extrados *O P*, and draw the joint lines through, which gives the direction and position of joints.

The vertical cross joints in vault may be drawn at pleasure, care being taken to "bond" by breaking joint, but the angle quoins of the groin must be treated differently, and for this reason: the extrados of the arch is set out on the plan as shown on the right hand half, and, by noting the joints 3 4 5 6 at *T U V W*, it will be observed that the vertical joints of the groins are set out to the mitre, which governs the size on the soffit. If the stones were set out less than this there would not be so good a bed, as this size should be the minimum.

The dotted diagonal lines on the half plan of the intrados show the mitre on the extrados, and the dotted diagonal lines on the half plan of the extrados show the mitre of the groin on the intrados. Although the extrados is here shown apparently as a finished face, yet in

VAULTING — *CYLINDRICAL*

FIG 10



— SKETCH OF VAULT —

FIG 5

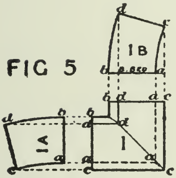


FIG. 6.

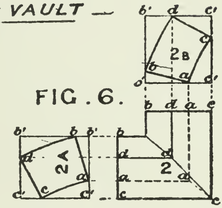


FIG. 5A

FIG. 6A

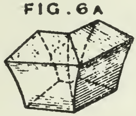


FIG. 6B

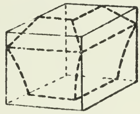


FIG. 9

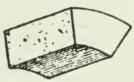


FIG. 7A

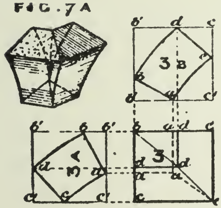


FIG. 7

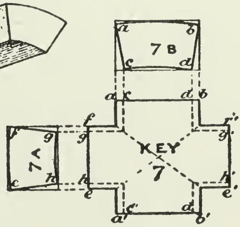


FIG. 8

practice it is not so, as it is generally left rough, and stepped out as a seating for concrete.

The stones which present any difficulty in the working in this form of vault are the angular groins, and these are the weakest part of the vault, on account of each stone acting to some extent as a corbel, and one corbel standing upon another, as indicated by the sketch (Fig. 10). Therefore care must be taken in working them true to shape and form.

The stones in other portion of the vault may be worked as those in a right arch.

The easiest way of working either of the groin stones is to take a block cubical in form, and containing it, as shown in Fig. 6 B; and, although in stones Nos. 3, 4 and 5, there is little waste attached to this method, yet it gives the best results, and is more correct in shape when worked than by using bevels. The danger of using bevels is in the application of them, that is to say, should there be the least deviation from the actual position in applying the bevel, the stone would not be true. This would not be of so much consequence were it an isolated block, but where it is surrounded by others, and forming a cylindric surface, it is of importance.

Fig. 4. Shows a quarter plan and profiles of the vault to a larger scale, for the purpose of showing more clearly the working of the groins; in actual work this is all that is necessary to set out, as the set of moulds of one groin will work the three others if "handed," that is worked in pairs.

Fig. 5. Is the springing stone. No. 1 is the bed mould, 1 *A* and 1 *B* the joint moulds.

Begin by working the bottom bed, this being horizontal, and scribe on the bed mould; next work the two ver-

tical faces or joints *c a d b*, and scribe in the joint moulds 1 *A* and 1 *B*, then the top splay joint *c d*, and lastly the curved soffit, care being taken to keep the mitre true.

Fig. 5A. Shows a sketch of this stone finished; the working of this differs very little from that of an ordinary arch stone.

Fig. 6. Is the second stone. No. 2 is the bed mould, and 2 *A* and 2 *B* the joint moulds.

Work the two beds parallel to each other, and of the extreme height of the joint mould from *a* to *d*, as surfaces of operation; labor need not be thrown away on these beds, as they may be roughly chiselled over and at the same time true: the mason should know just where to put the work that is necessary, in some cases, perhaps, a couple or three straight drafts being all that is required. This done, scribe in the bed mould No. 1 on the bottom and top bed. Work the vertical joints *c a d b*, scribing in the joint moulds 2 *A* and 2 *B*. The position of these moulds is given by the circumscribing rectangle, coinciding with the lines on the bed mould; next work the splay beds, and then the curved soffit guided by a convex templet, keeping the mitre also true.

Fig. 6A. Shows a sketch of the stone when finished.

Fig. 6B. Shows a sketch of the same contained within the circumscribing prism.

Fig. 7. Is the third stone. This is worked precisely as the last named in Fig. 6.

Fig. 7A. Shows a sketch of this stone when finished.

Fig. 8. Is the keystone No. 7.

In working this stone commence on the soffit plane, the points *a b* and *e f* and points opposite these being in this plane, which may be taken as a surface of operation. Scribe in the bed mould No. 7; the dotted lines *c d* and

g h show the finished arris on the soffit. Work the two joints *a b* and the two joints *e f* at right angles to the plane, and scribe in the joint moulds 7 A and 7 B, then the splay joints *a c*—*f g*, &c., and lastly the concave surfaces *c d* and *g h*. The mitres of intersection being here very obtuse must be carefully worked.

Fig. 9. Shows a sketch of one of the ordinary arch stones between the groins, which is worked similar to that of a right arch.

Fig. 10. Shows a sketch of the vault.

Plates XII, XIII, XIV, XV. DOMES AND PENDENTIVES.

The Dome may be generally described as a convex roof or vault, covering a circular elliptical or polygonal area.

The Pendentives are the corbellings resting on the internal angles of piers, and support the dome.

Fig. 1A. If a hemisphere or other portion of a sphere, *a b a*, be intersected by vertical planes, *a d c*, equidistant from its centre, the angular or spandril portion, *e e*, between the boundaries of the planes are pendentives.

Fig. 1. Shows half plan of square area, covered by dome and supported by pendentives.

Fig. 2. Shows sectional elevation of the dome and pendentives, taken through the centre line *E F* on plan.

For the making of the moulds, and working of this vault, a quarter plan only is required to be set out full size; but in order to show it more clearly the half is here given.

Begin by setting out on the plan (Fig. 1) the rectangle *A B E F*, the line *E F* being the centre line, and the line *C D* being the transverse centre line. The semicircle *E D F* is the half of inscribed circle, forming wall line of cornice and dome.

Set out the archivolt on impost caps at *A* and *B* as shown by hatched lines, which gives the span or opening of arches, and project on to springing line of section (Fig. 2).

At *c* as centre, with *c g* or *c h* as radius, describe semi-

circle *g j h for* soffit, and semi-circles concentric to this for lines of mouldings forming archivolt. The arch at crown *j k* must equal in height the width at springing *A G,* Fig. 1, so that the corbelling of pendentives start exactly in the angles at *A* and *B* on springing line at top of impost cap.

Divide the arch into any number of equal parts—in this example 7—and draw joints radiating from centre *c* as 1^a 2^a 3^a &c.; at extremities of joints as 1 *b* 2 *b* draw horizontal lines for beds (these are better if worked in conical or splay beds, but as it takes more material they are generally horizontal as shown at Fig. 3). Project 1 *b,* 2 *b* on to wall line of arch on plan, fig. 1, and with *C* as centre describe arcs 1 *B* 2 *B,* giving line of curvature of horizontal joints in pendative. The vertical joints may be drawn in at will, but are here shown as at 1 *B,* 2 *B,* 3 *B.*

It will be observed that the arch is panelled on soffit, and is shown on section by a chamfer, the detail being too small to show a moulding.

Set up the section of cornice No. 6 and project nosing on to plan (Fig. 1) as 6 *A.* For vertical joints divide cornice into 8 parts, this being a convenient number for stones in the dome, and also breaking joint with those in pendentives.

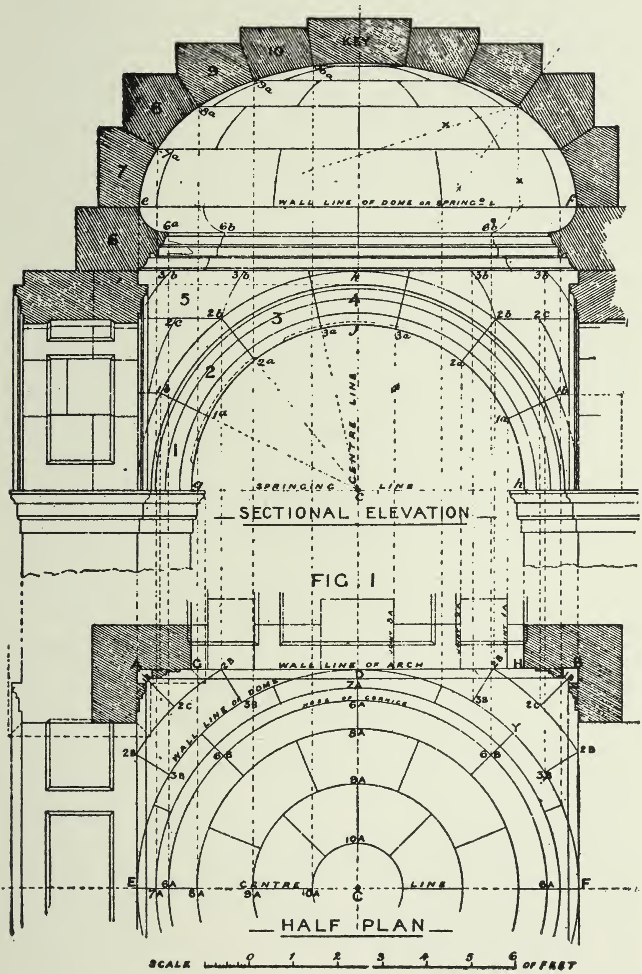
Draw in the joints which radiate from the centre *C* (Fig. 1) at 6 *A,* 6 *B,* and project on to the section (Fig. 2).

The wall line of the cornice, *e f,* Fig. 2, is the springing line of dome, and equals the width *E C F* on centre line of plan (Fig. 1).

On the line *e f* set up the curvature of dome, which is a semi-ellipse, and may be struck with the trammel or

DOME AND PENDENTIVES

FIG. 2



the curve may be traced through points in the intersection of lines.

For the joints divide the dome into any convenient number—in this example 9—as Nos. 7, 8, 9, 10, &c., and draw radiating lines perpendicular to the tangent of the curve, as at 7^a 8^a 9^a &c.; see construction as shown by dotted line *X X*.

Project 7^a 8^a 9^a &c., on to plan (Fig. 1), and *C* as centre, and 7 *A*, 8 *A*, 9 *A*, &c., as radii, describe semicircles which give horizontal lines in splay joints of dome.

For the vertical joints follow divisions of joints in cornice, the same number (eight) being required in each course, breaking joint, as shown on plan and section.

Fig. 3. Is a section on the centre line, showing corbelling out of the pendentive taken across the diagonal from *B* to *Y* on the plan (Fig. 1), the radius of which equals the distance from *C* to *B*, and the projection *B′*, *Y′* equalling *B*, *Y* on the plan (Fig. 1).

To work the Double Springer No. 1.

Fig. 4. 1 *A* is the bottom bed mould, 1 *B* is the top bed mould, and 1 *L* is the face mould.

The stone will require to be cubical in form, and the size of bed mould 1 *B*, and of the height of face mould 1 *L*.

Work the bottom bed and scribe in bed mould 1 *A*; work vertical joints *A B* and *A C* square with the bottom bed, and apply face mould 1 *L* to each joint and scribe in; next take the top bed *k j* parallel to bottom bed. Work out the check *D E F* right through, keeping the nosing of moulding fair or clean, and apply part of

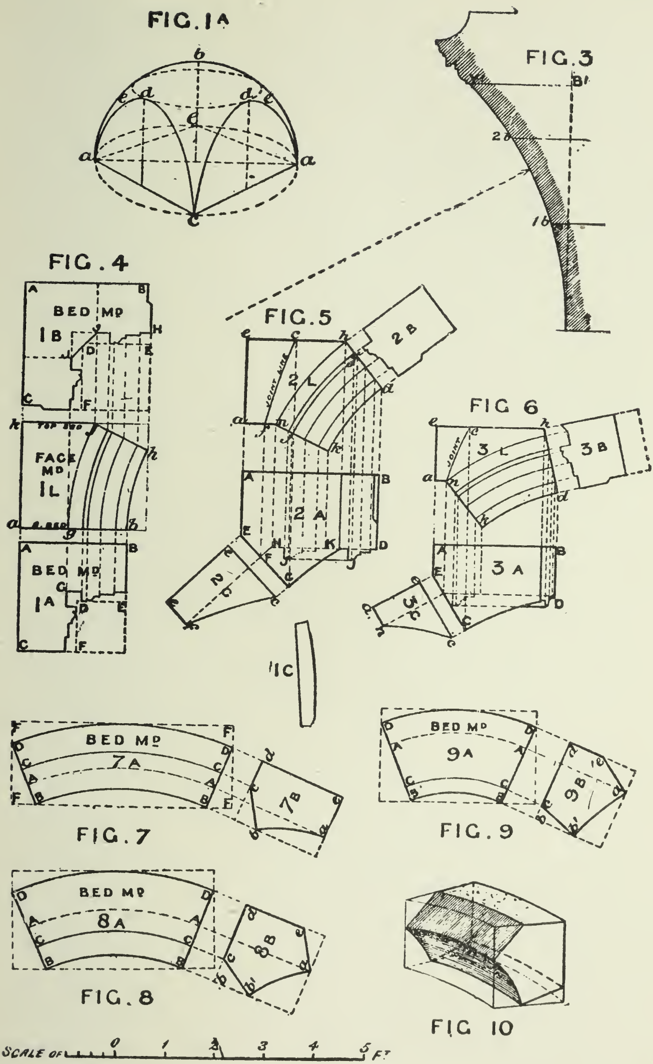


FIG. 1A
FIG. 3
FIG. 4
BED MD
1B
FACE MD
1L
1A
FIG. 5
JOINT LINE
2L
2B
2A
FIG 6
JOINT
3L
3B
3A
1C
BED MD
7A
7B
FIG. 7
BED MD
9A
9B
FIG. 9
BED MD
8A
8B
FIG. 8
FIG 10
SCALE OF 0 1 2 3 4 5 FT

face mould 1 *L* coinciding with the moulds marked on vertical joints *A B* and *A C,* which gives the soffit line *h b*, the splay joint *j h* and the nose and mitre line of the archivolt.

Work the splay joints *j h* and scribe in the archivolt, which is part of the bed mould 1 *A;* next the soffits and panels and archivolt mouldings guided by convex templets; lastly, work the small concave portion of pendentive, which starts imperceptibly at the angle *G* on the bottom bed, and increases to *J J* on the top bed.

The convex templet 1 *C* gives the curvature in the centre from *G*—1 *A,* to *D*—1 *B*. An obtuse mitre is formed on each side where the spandrel intersects the archivolt, and is shown by the segmental line *j g* on the face mould 1 *L*.

It will be observed that the archivolt on the bed mould 1 *B* is fore-shortened, but 1 *A,* being a square section, is used on all arch joints.

To work No. 2 Arch Stone.

Fig. 5. No. 2 *A* is the bed mould, 2 *L* the face mould, 2 *B* the joint mould of arch, and 2 *C* the joint mould of a portion of the pendentive.

This stone will require to be the size of the bed mould, and to the extreme height of the face mould 2 *L* from *k* to *h*.

Begin by working the top bed ***e c*** *h*—2 *L,* and scribe in bed mould 2 *A,* as *A B C D E*. Work the vertical joints *A B* and *E C* square with top bed, and scribe in the face mould 2 *L,* and joint mould 2 *C* respectively; point off vertical side *A E* and rough out section of pendentive *c f* from joint *E C* on to face line *N K,* and work draft through at *J J* for nosing. Apply part of

DOME

FIG. 12

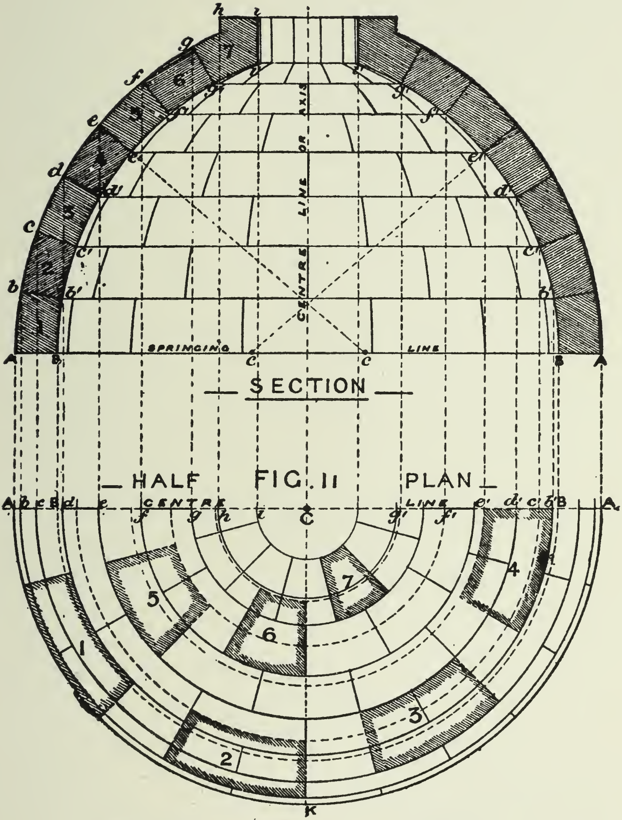
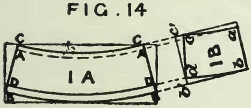
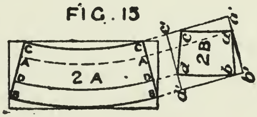


FIG. 14



BED Mo.

FIG. 15



face mould *h d f n k*—2 *L,* coinciding with the face mould marked in on vertical joint *A B,* and work the splay joints *h d*—*n k,* and bottom bed *a n.* Scribe in archivolt mould 2 *B* on joints *h d* and *n k,* and run the moulding through; clean in portion of pendentive *c f*—2 *C* intersecting with archivolt and forming obtuse mitre on the segment line *n* to *h,* and lastly, work panelled soffit.

Fig. 6. No. 3 arch stone is worked in a similar manner to the foregoing No. 2 (Fig. 5).

No. 4, the keystone, needs but little explanation, it being worked similarly to that of a right arch, with the exception of the mitre of the pendentive, which is here very obtuse and loses itself at *k.*

The section mould at each joint is 3 *B* (Fig. 6), taken to the dotted line.

Note.—The dotted lines show the projection of coinciding points in the face and bed moulds of Figs. 4, 5, and 6.

The section of cornice directly under dome is shown on Fig. 2, No. 6. A bed mould for this is required and also convex templets for the mouldings and fillets, these are obtained from the plan (Fig. 1), 6 *A* being the nose line.

The working of this stone presents no difficulty.

To work the Voussoirs in the Dome.

The shape of stone for working one of these is first, a rectangular prism, of the extreme length of the bed mould 7 *A* (Fig. 7), as shown by circumscribed dotted lines *F F,* and of the height of joint mould 7 *B,* and second, that of a segment of a hollow cylinder, as shown in sketch (Fig. 10), which contains the finished block.

Fig. 7. 7 *A* is the bed mould, and 7 *B* the section or joint mould of springer, or first stone in dome.

Begin by working the bottom bed *a e*—7 *B,* and scribe on the bed mould 7 *A,* the dotted line *A A* being the wall line on bottom bed, which must be worked fair to preserve the arris *a.* Work the joints *B D* square with the bed, and scribe in the joint mould 7 *B.* Work off the top bed *c d* and splay joint *c b,* a convex templet giving the arris *B B,* and lastly the concave of intrados *a b.*

The back *D D* is left rough.

Fig. 8. To work the second stone in dome No. 8. 8 *A* is the bed mould, and 8 *B* the section, or joint mould.

Work the top bed, *b c d*—8 *B* and scribe in bed mould, 8 *A,* to the extreme size, as *D D, B B,* the dotted line *A A* being the horizontal arris of joint and soffit at *a*; the line *C C* top line of splay joint *c*; and the line *B B* the horizontal arris of joint and soffit at *b* 1.

Work the joint, *B D* square with the top bed, and scribe in the joint mould, 8 *B*; at points *B B,* at depth *b* 1, work a concave draft, and draw the horizontal line of joint and arris of soffit. Next work off the splay joint *c b′,* also the splay joint *a e,* and lastly the concave surface of intrados.

The back *D D* is left rough.

Fig. 10. Shows a sketch of this stone completed.

It may be mentioned that the stones Nos. 2 and 3 (Figs. 5 and 6), previously described, are worked to one hand; for the opposite hand, the same moulds and templets will do, if reversed.

No. 5 (Fig. 2), is a plain spherical stone in the pendentive, and is worked similarly to those in the dome, as above described.

To construct a Spheroidal Dome, with an aperture at the apex or top. The bed-joints are conical surfaces, and terminate on the extrados and intrados, in horizontal circles. The vertical joints are contained within a plane, which intersects with the axis of the dome.

Fig. 11. Shows half-plan of the dome.

Fig. 12. Shows section of the dome through the centre.

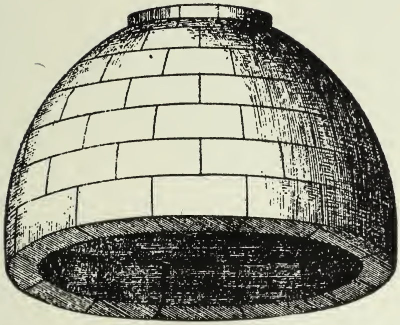
For the making of the moulds, and working this dome, a quarter only is necessary to be set out full-size, but in order to show it more clearly the half is here given.

Begin by setting out on the plan (Fig. 11), the centre lines, *A C A* and *C K*. With *C* as a centre and *C A* as radius, describe the semicircle *A K A*, giving the extreme boundary of exterior surface, or extrados of dome. The thickness of the dome having been determined as *A B*, with *C* as centre and *C B* as radius, describe the semicircle *B B*, as shown by the dotted line, giving the extreme boundary of interior surface, or intrados of dome. Project lines *A* and *B* to springing line, Fig. 12, and with *c c* as centres set up the section of dome, and divide the same into any number of equal parts for bed-joints as may be convenient (in this example, seven), as *b c d e f g*, and draw radiating lines for the joints from centre, *c*. Project *b c d e*, &c., on to plan (Fig. 11), and with *C* as centre describe semicircles *b c d e*, &c.; the plan of the arris of horizontal bed-joints on exterior is thus obtained. For the arris of horizontal bed-joints on interior surface, project *b c d e*, &c., on to plan, and draw the semicircles *b′*, *c′*, *d′*, *e′*, &c., shown by the dotted lines on right-hand half.

For the vertical joints each course will consist of the

DOME

FIG. 13



— SKETCH OF DOME —

FIG. 16

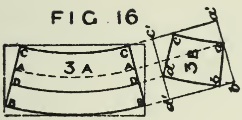


FIG 17

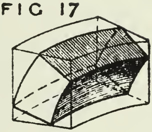


FIG 18

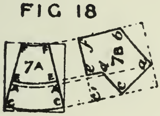
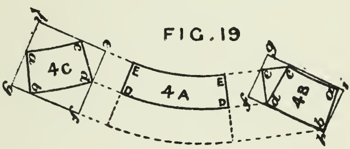


FIG. 19



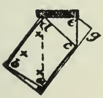


FIG. 20

FIG. 21

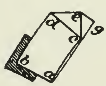


FIG 22

FIG. 23

same number of stones (in this example, twelve), breaking joint directly over each other and diminishing in size from bottom to top course. These are set out on the plan.

The stones "hatched in" on the plan (Fig. 11), show the projection of one voussoir in each course, as 1 2 3 4 5 6 and 7, and, being equal and similar stones, and alike in situation, one bed mould to each course only will be required.

To work the Voussoirs.

The shape of rough block required for working these stones by this method is a rectangular prism of the extreme length of the bed mould, as 1 *A* (Fig. 14), shown by the circumscribed line, the height being that of the joint mould 1 *B;* and secondly, that of a segment of a hollow cylinder, as shown in sketch (Fig. 17), which contains the finished block, the arrises only touching the boundaries of the cylinder.

Fig. 14. 1 *A* is the bed mould, and 1 *B* the section, or joint mould, of springer, or No. 1 stone.

Begin by working the bed, *a b*—1 *B,* and scribe in bed mould 1 *A.* Work the joints *B C* square with the bed, and scribe in joint mould 1 *B.* Work the top bed *b′ c′* as a surface of operation, and scribe in the line *D D,* which gives the top line of arris of convex surface and of splay joint. With the templet *C C* at *c* work the horizontal draft, giving the arris of joint and of concave surface. Work the top, *d c,* to lines as given, and the inside concave surface *a c*; and lastly, the outside convex surface, *b d,* using templets made at *a c* and *b d* for guidance.

Fig. 15. To work the second stone (No. 2).

2 A is the bed mould and 2 B the section, or joint mould. Work the bottom bed a' b' as a surface of operation, and bed d' c' parallel to it. Labor need not be thrown away on these surfaces, or beds, as the arris, a a on one bed and d d on the other, is all that is required to be kept fair; the other portion may be roughly chiselled off, and at the same time kept straight. Scribe in the bed mould on both ends, as B C—B C, and work the joints B C square with same; scribe in the joint mould, as b a d c, to each joint. With the templet C C at c work a horizontal draft, and draw a line parallel to C', giving the arris of joint and of concave surface. With the templet D D scribe in line on the top bed, giving the arris of top joint and of convex surface. Work off the splay joint d c to the lines thus given. On the bottom bed, with templet A A scribe in line, giving the arris of bottom joint and of concave surface. With the templet B B at b work the horizontal draft, and draw line parallel to b', giving the arris of bottom joint and of convex surface. Work off the splay joint to the lines thus given, and inside concave surface a c, and lastly outside convex surface b d, using templets made at a c and b d for guidance.

The stones in the other courses of the dome are worked in a similar manner to those last described, except the top course, or rim.

To work the Rim of Aperture in Dome, being the top, or No. 7, course.

Begin by working the top bed c' f, and scribe in the bed mould 7 A. Work the joints C F square with bed, and scribe in the joint mould 7 B. At a work a hori-

zontal draft straight to *a,* and scribe in the templet *A A,* giving the arris of bottom joint and concave surface; then work the bottom joint and spherical surfaces *a b* and *c d e.*

There is some difference of opinion as to the best method of working the voussoirs in a dome, with respect to waste of material and labor. Perhaps for the first and second courses, and also the courses near the apex, no better method can be followed than the one just described, and, as before explained, in reference to vaulting. This method is simple, gives the best results, and the stones are truer in form when worked than by using a number of bevels. However, another method is here shown, which saves much material and labor, although greater care is required in the execution.

Another Method of Working the Voussoirs.

Fig. 19. Let 4 *A* be the bed mould of stone in fourth course of dome. (This being one of the courses in which there is much waste by the previous method of working, and is shown by section 4 *C,* at line *e f g h.*)

For the joint mould, 4 *B,* transfer No. 4 from section (Fig. 12), as *d c b a.* Draw *e d* parallel and *e c* vertical to the base, or springing line; *f g h i* is a rectangle, circumscribing the mould and giving the size of stone required. When compared to that of 4 *C, e f g h,* the difference is at once seen.

Select a stone sufficiently large, so that all the surfaces and arrises are contained within it.

Fig. 20. Begin by working a plane surface of operation, as *e d,* and apply templet 4 *A,* and scribe in as *D E, D E.* Work joints *D E* square with the bed; these

require careful working, a portion of the joint being outside the line of square, as at *X X X* but the one portion of joint having been worked, the other is obtained by means of the straight-edge. Apply joint mould to each joint, as *d c b a,* and scribe in.

Fig. 21. Shows the next operation of working the convex spherical surface, by the guidance of a bevel, the stock of bevel being applied in the direction of a line radiating from centre *C,* as the joint lines *E D*—4 *A.*

Fig. 22. Shows the third operation, the line *b* being drawn parallel to *d*; a bevel is used, giving the bottom splay bed, *b a.*

Fig. 23. Shows the fourth and last operation, the angular portions, *e g d c* being cut away and bevel used for splay joint; and the concave spherical surface is worked by the guidance of a templet made from *a c.*

It will be observed in the working of this stone that by this method the accuracy of the work depends almost entirely on the first plane surface of operation, and, should any errors occur in applying the bevels from this bed, the stone will not be of the shape and form intended.

The stones in other courses of dome may be worked in a similar manner.

Plates XVI, XVII, XVIII, XIX. GROINED VAULTING.

To construct a Groined Vault, in four compartments, square on plan, and supported by a central shaft or column, with wall, transverse, and diagonal ribs.

Fig. 1. Is the inverted skeleton plan of vault, showing the general arrangement of compartments: *A A* being the wall ribs, *B B* the transverse ribs, crossing the vault at right angles to the wall, *C C* the diagonal ribs, spanning across from corners to the shaft, and *D D* the vaulting surface.

Fig. 2. Shows the inverted plan of one compartment, or one quarter of the vault, with elevation of the wall, transverse and diagonal ribs, each being of equal height at the apex, and the ridge line of vaulting surface being also level throughout.

For the purpose of making the moulds, and the working of this vault, a small portion of the plan (one-sixteenth only), set out to full size, is all that is necessary, the remainder being a repetition; but, in order to show the setting out more clearly, a quarter of the plan is here given.

Begin by setting out the wall lines of vault, then the centre lines of wall ribs *A B* and *A C*, the transverse ribs *B D* and *C D*, and the diagonal ribs *A D* and *B C*, and set off on each side of the centre lines the width of their section.

Before proceeding further it is necessary to determine the position of the feet of ribs at the springing; these generally depend on the plan of the abacus of cap, and it is also a matter of arrangement, as well as of taste and design, so that no fixed rule can be given.

In this example the ribs are arranged so that the nosings are equi-distant from the point of intersection of the centre line of ribs at *A B C D,* in order that the wall ribs and transverse ribs may be of the same curvature, and also that the opening or span between the nosing of springers may be equal.

Having set out the position of the springers at *A B C D* on plan, the next process is to find the elevation or contour of the ribs. This is generally governed by the wall ribs, which have some opening or arch in the wall below them, regulating to some extent the form of vaulting. In some cases, perhaps, it may be preferable to begin with the transverse or diagonal rib, but this again depends on the shape of the vault.

In this example the contour of the transverse and wall ribs are similar, their span being equal, as before explained.

Begin by drawing the wall rib first. Take the centre line *A B* on plan, and make use of it as a base or springing line. Erect a perpendicular as a centre line at *M* on the plan, and on this set up the height of vault, as at *E*. Let point No. 1 be the centre from which the wall rib is struck, and with this as a centre, and nosing *G* as radius, draw the segment line *S* for the nose of rib on the soffit, cutting the centre line at apex *E*; gauge on the width of members of the rib, from the line of soffit *S* as *H J K,* and with the same centre, No. 1, draw the segment lines through these points, thus forming the

wall rib. This is also the elevation of the transverse rib.

The profile of the diagonal rib is now to be obtained, and the first consideration is the shape of the vault. If a horizontal section be taken through any one of the compartments, above the springers, and the vaulting, or filling in, between the ribs is rectangular in shape and parallel to the sides, the courses of stone forming the vaulting surfaces are level, and the upper edges of the diagonal ribs, upon which the filling-in rests, are portions of elliptic curves. These curves are obtained by ordinates, the curvature being subordinate to the wall rib; this is sometimes done, but as the elliptic rib entails more work both in the setting out and in the execution, the simpler method of using compound circular curves is generally adopted, and with perhaps better results constructively. The ribs are thus made geometrically regular, while the filling-in surfaces take their chance as it were, and are adjusted to the curvature of the ribs, and although twisting to some extent, yet do not offend the eye, which is guided mainly by the principal lines, and not the surfaces.

Another consideration is the separation of the ribs at one level, at the point where they become fully developed. The more equally the ribs can be grouped together at the springing, without projecting at unequal distances before each other, the better it is for their separation or clearance, the advantage of this being, that the winding in the vaulting surface is much reduced, and is free from that ploughshare-like twist, to which objection is sometimes made. The ribs are also equal in depth and of the same cross section, and the setting out and the working generally are easier. In some cases it may be

CROINED VAULTING

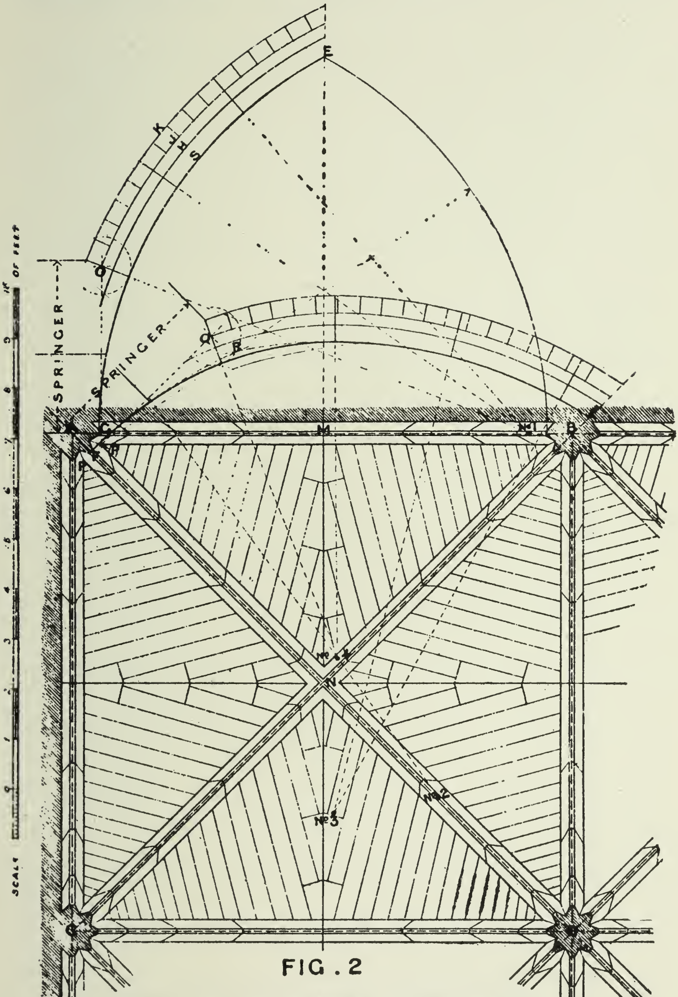


FIG. 2

PLAN OF ONE QUARTER OF THE VAULT AND ELEVATION OF RIBS

impossible to do this, and the ribs are then arranged to suit the conditions of the case.

In this example the contour of the diagonal is struck from centres, and these may be varied to suit any adjustment of curvature.

The point at which the feet of ribs is struck should be on the springing line, neither above nor below, for if above the rib would be stilted, and if below an acute angle would be formed with the springing line, neither of which results is pleasing.

Let *A D* the centre line of diagonal rib on plan (Fig. 2), be the base of springing line for the elevation of rib; produce the centre line *C B,* which is perpendicular to *A D,* as the centre line of elevation, and on this set up, from the base line to the apex of the soffit of rib, the height *N L,* equal to the height *M E* on the elevation of the wall rib. Next in the elevation of wall rib, find the point of clearance, or where the rib separates from the springer, and the full section of rib is obtained; this will be the point in the upper edge of the rib vertically over the point where the sides of the rib intersect at *P* on plan. At *P* erect a perpendicular to the springing line *A B,* cutting the upper edge of rib at *O* in elevation, which is the point of separation, or where the wall rib is fully developed, and clears the springer. Through the same point *P,* erect a perpendicular to the springing line *A D* on the diagonal, and set off the height *F Q,* equal to the height at wall rib of *G O;* the diagonal rib thus clears the springer at point *Q,* the back edge of the rib at vaulting surface.

Two points are already given in the curve of the diagonal rib, namely at *F,* the springing, and at *L,* the apex, but a third is required. Now at point *Q* describe an

GROINED VAULTING

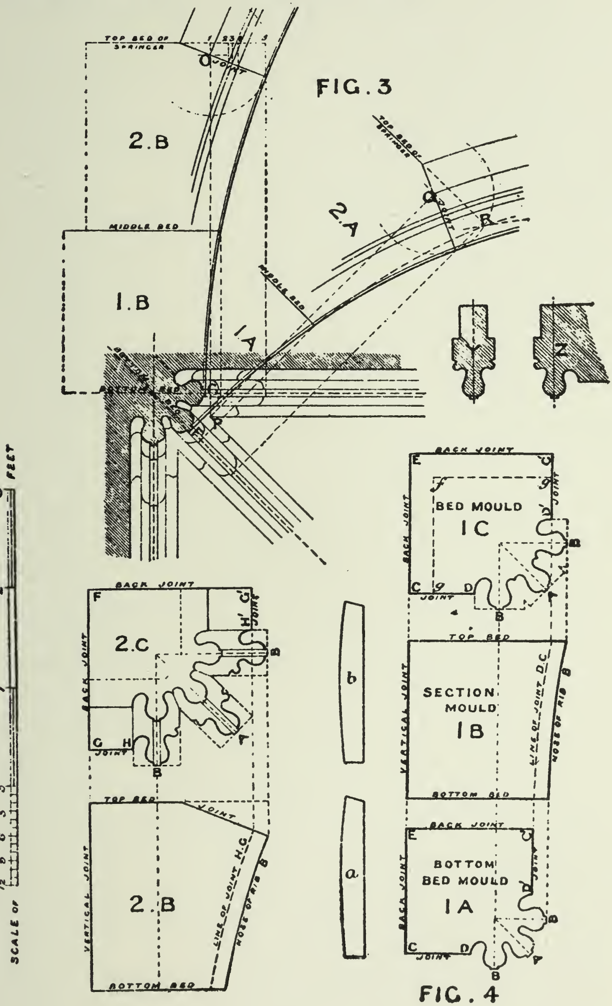


FIG. 3

FIG. 4

FIG. 5

arc with radius equal to the depth of the rib as at *O*, and it will be at once evident that the arc furnishes a point through which the curve of rib must be drawn. Commence on the springing line *A D*, and find a centre by which the curve may be drawn from *F*, to touch the arc whose centre is *Q*, but as this throws the curve too high, and would make a cripple, find a centre, No. 2, that takes the curve still higher, that is to *R* as shown by the dotted line. Now find a centre as No. 3, and draw curve to *R* from the apex *L*. An intermediate radius is now required, by which a curve may be drawn touching the arc whose centre is *Q*, and intersecting the other curves Nos. 2 and 3. This is found at No. 4, and the curvature of the diagonal rib thus obtained is easy and graceful, retaining also the pointed form. Gauge on the width of members of the rib from the line of soffit, and with their respective radii draw curves forming the elevation of the diagonal rib.

The radii and centres are best found by repeated trials.

The next thing to be done is to arrange the joints of the springers and ribs, and the filling-in to the vaulted surfaces.

The joints of the springers are usually worked in horizontal or level courses, except a portion of the top bed, where the ribs separate and are fully developed; this portion is inclined or splayed from the level bed, and abutment joints are thus formed which radiate to their centres.

The joints for the ribs may be drawn to any convenient length to suit the size of stones, and they must radiate to the centres from which that part of the rib is struck.

The diagonal ribs which intersect at the apex and

form the key are the same in curvature, and will properly mitre into each other; the arms or stumps at each side of the intersection are drawn at will to any convenient length.

The filling-in to the vaulted surfaces is in narrow bands of stone, four or five inches wide, and with beds slightly radiating. These bands start from the point where the ribs separate at the top of springers, and are continued in parallel courses until they meet obliquely at the apex, taking then the form of key blocks; these key blocks are rack shaped, and derive support from the bands which abut against them, and also rest on the wall ribs and mitre junctions in the centre of the vault. The filling-in bands being narrow on the face the twist to each stone is so small as to be scarcely perceptible; moulds may be made to these if desired from the elevation of wall and diagonal ribs, but the twist on the stones is usually worked on the scaffold at the time of fixing, this being the most economical way. The key blocks also are simple in construction, the making of moulds and working of the stones presenting no difficulty.

Attention may now be directed to the setting out in detail and to the working of the various stones.

Fig. 3. Shows the setting out of the springers to a larger scale. The section moulds for diagonal and transverse ribs are given at *Y*, and that of the wall rib, which is slightly different on the wall side, at *Z*.

The centre lines having been drawn, the section moulds of ribs *Y* and *Z* are applied until the position of the ribs is arranged equi-distant from the point of intersection of the centre lines, as before explained.

The notation is the same as that of Fig. 2.

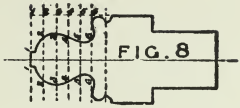
Fig. 4. Shows the bed and joint moulds of No. 1, or bottom stone in springer.

1 *A* is the bottom bed mould, 1 *C* is the top bed mould or middle bed (this also will be the bottom bed mould of No. 2, or upper stone in springer at dotted line *g f g*), and 1 *B* is the section mould taken through the centre line of wall rib.

Commence by working the back joints *E C* and *E C′* (which may be taken as surfaces of operation), and scribe on the section mould 1 *B* on each joint. Work the bottom and top beds square from back joint, these being parallel to each other, and scribe in the bed moulds 1 *A* on bottom bed and 1 *C* on the top bed. Work the two concave joints *C D* and *C′ D′*, guided by a convex templet, and the nosing of rib from *A* to *A* and the nosing of ribs *B* to *B*, guided by the convex templets *a* and *b*. The moulding is now to be worked, using small reverses and templets for guidance.

Fig. 5. Shows the bed and joint mould of No. 2 or upper stone of the springer.

1 *C* (Fig. 4) is the bottom bed mould, 2 *C* is the top bed mould, and 2 *B* is the section mould taken through the centre line of the wall rib. Work the back joints *F G* and *F G′*, and scribe on the section mould 2 *B* on each joint. Work off the bottom bed square from the back joint, scribing on the bed mould 1 *C* (Fig. 4) to the dotted line *f g*; next work off the top bed square from the back joint and parallel to the bottom bed, and the splay joint for the seating of diagonal rib. The bevel for this may be obtained from 2 *A* (Fig. 3) or the nose line may be squared down from the top bed and the depth gauged on. On the centre lines of the top bed scribe on the section of rib moulds *Y* and *Z*.



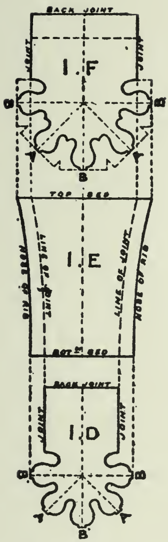


FIG. 6

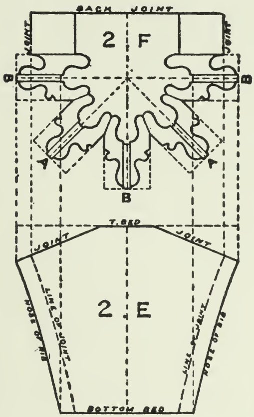


FIG. 7

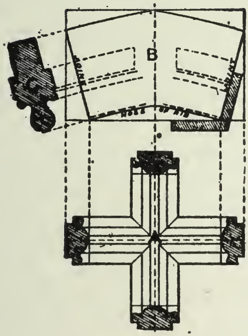
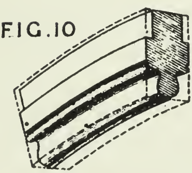


FIG. 9

FIG. 10



SKETCH OF RIB

Work the two concave joints $G\ H$ and $G'\ H'$, also the nosing of rib from A to A and the nosing of ribs from B to B, guided by convex templets. The moulding is now carefully worked, using small reverses and templets for guidance.

The springers when worked will truly mitre from the springing to the separation of ribs.

Care must be taken that the centre lines of the ribs are vertically over one another, or in the same vertical plane, as shown in Fig. 5—2 *C*, in which the mould No. 1 *C* for the bottom bed is marked on, and again in Fig. 7—2 *F*, where the mould 1 *F*, for the bottom bed, is also marked on.

The moulds should always be made this way with the sections vertically over one another.

It will be observed in the bed mould 2 *C* (Fig. 5) that although the moulding to ribs is given it is only approximate, and cannot be worked to accurately, because it is here foreshortened, and consequently a little distorted. This may be seen by reference to Fig. 3, the plane at 1, 2, 3, 4, 5 being that to which the mouldings are projected from the splay joint. The position of nosing, however, is correctly given, starting square down at the depth of the splay joint from the horizontal bed.

The section of the rib moulding at the middle bed, or at any horizontal line of the springer, may be obtained by projection. Divide the square section of the rib into any number of parts as in Fig. 8 at 1 2 3 4 5 6. Set off these points on the elevation of the rib, and from the centre draw the segmental lines through, cutting the horizontal line or bed; transfer these points of intersection to the centre line of the rib on plan, and draw lines through square from the centre line, and make

them equal to 1 1—2 2—3 3, &c., of square section, and draw the curves through these points, giving the true section at horizontal level.

Fig. 6. Shows the bed and joint moulds of springers of No. 1 or bottom stone at *B* and *C* on the plan (Fig. 2).

1 *D* is the bottom bed mould, 1 *F* is the top bed mould, and 1 *E* is the section mould taken through the centre line of wall rib *B B*.

Fig. 7. Shows the bed and joint moulds of No. 2 or upper stone springers at *B* and *C* on the plan (Fig. 2).

1 *F* (Fig. 6) is the bottom bed mould, 2 *F* is the top bed mould, and 2 *E* is the section mould taken through the centre line of wall rib *B B*.

The moulds for the central springer at *D* on the shaft are identical with the last-named (Fig. 6 and Fig. 7). The centre line at *B B* being half of the mould, this half scribed on the stone and then reversed for the other half, gives a completed whole.

These last-named springers are worked precisely as those already described, the same templets as before being used for the nosing of ribs and concave joints.

Fig. 9. Shows the bed and section mould of the keystone at the intersection of the diagonal ribs. *A* is the bed mould, *B* is the section mould, taken vertically through the centre, and *C* is the section mould of the rib.

Work a plane bed as a surface of operation, and scribe in the bed mould *A* on the soffit. Work off the splay joints to bevel, and scribe in the section mould of rib *C* on each joint; work out the square checks on each side of ribs, and cut the nosings to a concave shape, guided by convex templets. Now run the mouldings in on each stump to their intersection, forming mitres,

cut off the back if required, and take out the rebate for vaulting surfaces.

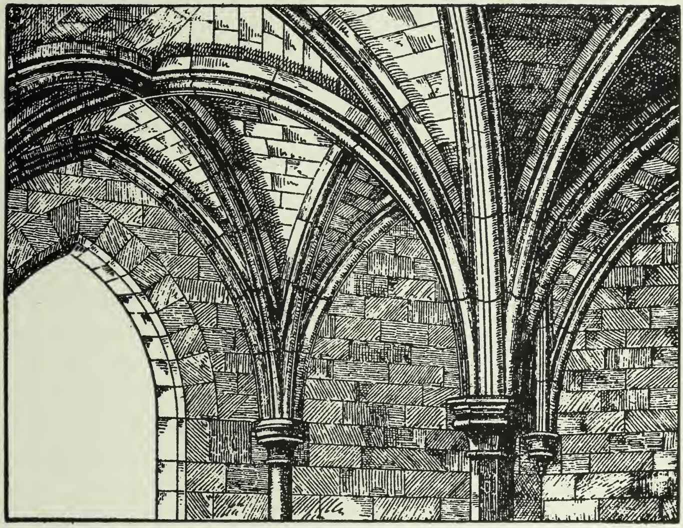
Fig. 10. Shows a sketch of the rib.

The working of this requires but little description, it being treated as a simple arch stone. A plane surface is first formed; on this the face mould is scribed, and the joints which radiate from the curve of the soffit are then squared through, and the section mould of rib is scribed in on each joint. The stone is next worked to a parallel thickness, the rebate for vaulting surface being taken out and the moulding run through, guided by convex templets and reverses.

Fig. 11. Shows a sketch of part of the vault.

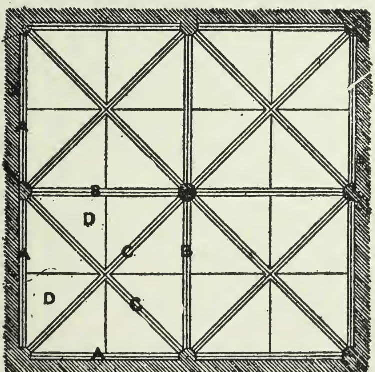
GROINED VAULTING

FIG. II



SKETCH OF PART OF VAULT

FIG. I



PLAN OF VAULT

Plates XX, XXI, XXII, XXIII.
GROINED VAULTING.

To construct a Groined Vault, square on plan, with wall, diagonal, intermediate and ridge ribs.

This vault is somewhat different to the one previously shown on pages 89 and 90, in having intermediate ribs, ridge ribs and bosses.

Ornamental bosses are introduced into these vaults, as it is not possible to nicely mitre the mouldings of the ribs, at the intersection of the apex or ridge, on account of the different inclinations of the ribs. The mouldings, therefore, die into the bosses, and the difficulty is got over. The bosses also give strength and richness to the vault.

Fig. 1. Is the inverted plan of vault, showing the general arrangement of ribs, *A A* being the wall ribs, *B B* the diagonal ribs, *C C* the intermediate ribs, *D D* the ridge ribs, and *E* the vaulting surface, or filling in, and *F* the bosses.

Fig. 2. Shows the inverted plan of one quarter of the vault, with elevation of the wall, diagonal, intermediate, and ridge ribs, each being of equal height at the apex, and the ridge ribs being also level throughout.

For the purpose of making the moulds and working the vault, only one quarter is necessary to be set out, the remainder being a repetition. Begin by setting out the wall lines of vault, then the centre lines of wall, ridge, intermediate, and diagonal ribs, and draw circles for bosses, at the intersection of ribs.

GROINED VAULTING

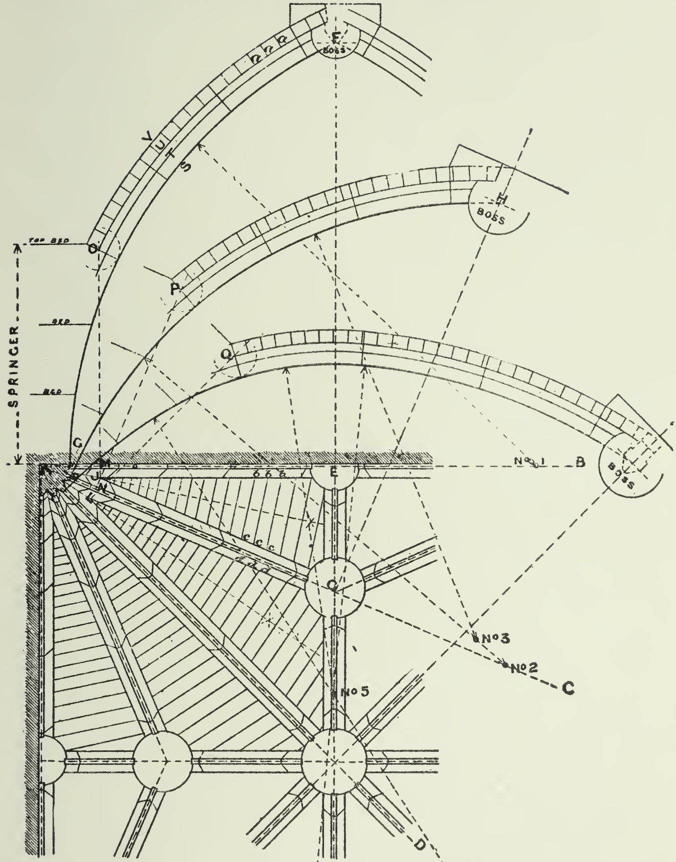
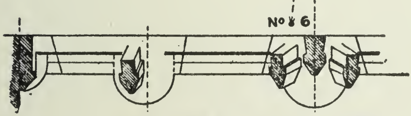


FIG. 2



ELEVATION OF RIDGE

Determine the position of the feet of ribs, at the springing line, as shown at Fig. 3. The noses of these ribs are arranged so as to touch a segmental line (the abacus of cap upon which the springer rests being segmental). Gauge off on each side of the centre lines the width of ridge, intermediate, diagonal, and wall ribs; the first three are equal, but the wall ribs are only a little more than half the width of the others, in order that the nosings should be of one size.

To complete the portion of the plan, the filling in, to the vaulted surface, must now be set out.

Narrow bands of stone, or chalk, of various widths, but generally parallel, are mostly used. In the spandrel pieces on the plan, between the wall and intermediate ribs, and intermediate and diagonal ribs, the joints are set out at right angles to a line bisecting the angle formed by these ribs.

Space out these bands, on the rebate line of wall rib, on the elevation Fig. 2, as at *a a a,* and project on to the side of the wall rib, on plan, as at *b b b;* draw the joints at right angles to the line of bisection, which produce to side of the intermediate rib as *c c c.* Square the joints across this rib as shown at *d d d;* the points thus obtained give the position of the bands, between the intermediate and the diagonal rib, which are drawn similarly to the preceding.

The next process is to find the elevation, or contour of ribs, which in the present example is governed by the wall rib, and this regulates to some extent the form of vaulting.

Begin by drawing the wall rib, taking the centre line *A B* on plan as a base or springing line, then at *E,* the centre of side of vault, erect a perpendicular as a centre

line, and set up the height of vault as at *F*. Point No. 1 is the centre from which the wall rib is struck, with this point as a centre, and the distance to nosing *G* as radius, draw the segment line *S* for the nose of rib on the soffit, cutting the centre line at the apex *F*, which may be also called a datum line, this line being the height to which all the ribs are drawn. Next gauge on the width of the members of rib, from the line of soffit *S*, as *T U V*, and with the same centre No. 1 draw segmental lines through these points, thus completing the wall rib.

The elevation of the intermediate and diagonal ribs is now to be obtained, and the first consideration is the separation of the ribs at one level. This separation of the ribs is of primary importance both in the working and the setting out, and has been fully explained in the previous section.

For the elevation of the intermediate rib, commence on the centre line of rib *A C* on the plan, and at *G* erect a perpendicular to *A C* as the centre line; on this set up the height *G H*, equal to *E F*, on the elevation of the wall rib.

Next find the point in the elevation of the wall rib, where the rib clears itself and separates from the springer. At *J* erect a perpendicular to springing line *A B*, cutting the upper edge of the rib at *O*, in elevation, which is the point of separation of the rib, or where it is fully developed, and clears the springer. Through the same point *J* erect a perpendicular to the springing line *A C* on the intermediate rib, and set off the height *N P*, equal to the height of wall rib at *M O*. The intermediate rib thus clears the springer at point *P*, the back edge of rib at vaulting surface. Two points are already in the curve of the intermediate rib, namely, at *R* the springing,

and at *H* the apex, but a third is required. Now at point *P* describe an arc, with radius equal to the depth of the rib as at *O,* containing a point through which the curve of rib must be drawn. Commence on the springing line *A C,* and find by trial a centre, and draw the curve from *R* to touch or approach the arc, whose centre is *P*. Find a centre No. 2, and draw the curve from *R* towards the arc, and with centre No. 3 continue the curve to apex *H*. From the line of soffit gauge the width of members of rib, and with centres Nos. 2 and 3 draw the curves, forming the elevation of the intermediate rib. Care must be taken that the curves are regular, and that cripples are avoided.

The elevation of the diagonal rib is to be next obtained, and the method adopted is similar to the foregoing, or as in the preceding example. Centres are found by trial, as at Nos. 4, 5, and 6, and the curves drawn from them.

The next thing to be done is to arrange the joints of the springers, and the ribs, and these may be drawn to any convenient size. The joints of the ribs, above the springers, radiate to their respective centres, and the joints of the springers will have horizontal beds.

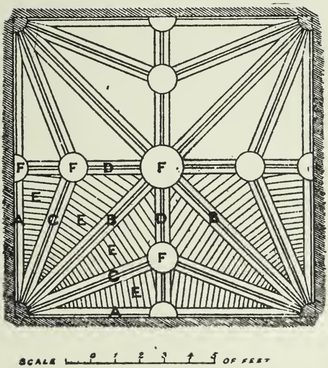
The moulds and templets for the springers are made, and the stones worked similarly to those already described in preceding example.

The ridge ribs and the bosses have now to be described, for the purpose of making the moulds, and working of the stones.

Fig. 4. Is the bed mould and sections of the central boss stone, *A* being the bed mould, *B* the section mould, through the centre of the boss, and curved ribs, and *C* is part section mould, through the centre of boss, and ridge ribs. It will be seen that neither of these last two

PLATE XXI.

FIG. 1



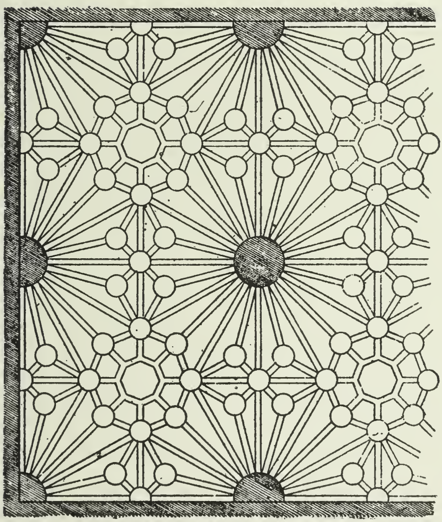


FIG. 8

moulds can be applied direct on the stone, but are used to obtain the bevels of the joints, curvature and position of the ribs, and contour for the carving, as well as to show the true form at those sections.

The stumps, or arms, in this example are perhaps longer than they need be, but are here emphasized to show more clearly the working. The four joints of the diagonal ribs radiate to their centres, and form a key, the other four joints are arranged so as to form skew backs, upon which the ridge stones are supported.

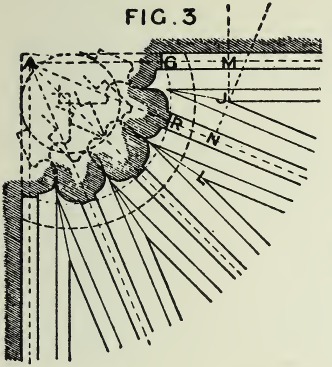
There are several ways of working these boss stones, and the one now to be described is similar to that adopted by the old Gothic masons, which has also simplicity to recommend it. There must necessarily be waste of stone as well as labor, whatever method is chosen.

First form a plane surface of operation, as *a b* on the section *B,* so that when fixed, this bed is horizontal, and on this scribe in the bed mould *A*. Work off the splay joints *e f* to receive ridge, the bevel being obtained from the section *C,* and the radiating joints *c d,* for the diagonal ribs, getting the bevel for these from section *B,* scribe in the section mould of rib *E,* to splay joint for the ridge, and the section mould of rib *D,* to the radiating joint for the diagonal ribs. Now work the stumps and mouldings in against the boss, using templets made from section moulds *B* and *C* for guidance.

The boss may be shaped out and carved before fixing, or left rough from the point, and carved after fixing, the latter method being generally adopted.

Fig. 5. Is the bed mould and sections of intermediate boss stone, and part of the ridge, *F* being the bed mould, *G* the section mould, through the centre of the boss and ridge rib, and *H* part section mould through the boss

FIG. 3



SCALE OF 1 2 3 4 5 6 7 8 9 10 11 12 INCHES

FIG. 6

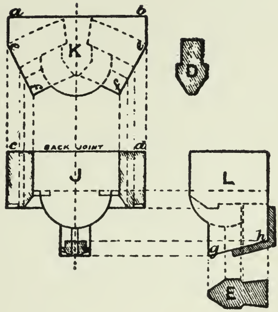


FIG. 4

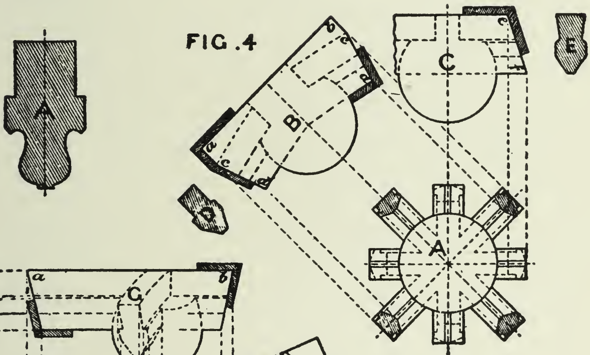
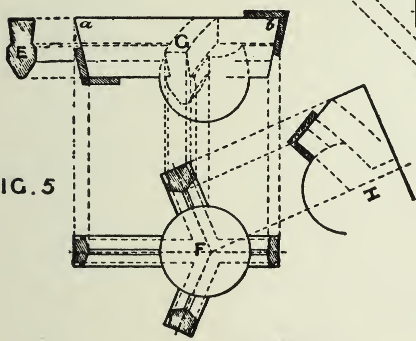


FIG. 5



FOR DETAILS

SCALE 0 1 2 3 4 OF FEET

and intermediate ribs. Neither of these last two moulds can be applied, but are used for the purpose of obtaining bevels, curvature, and position of ribs, &c., as in the case of central boss stone (Fig. 4).

First form a plane surface of operation, which will be horizontal, as *a b* on the section *G,* and on this scribe in the bed mould *F,* then rough the stone out to shape and work off the joints, the bevels being obtained from the section moulds *G* and *H,* scribe in the section moulds *E,* for the ridge rib, and *D* for the intermediate ribs. Next work the ribs in against boss, and complete the mouldings; the boss may be treated as in Fig. 4.

Fig. 6. Shows the bed mould, and also sections of key to ridge and wall ribs, *J* being the bed mould, *K* and *L* the section moulds.

First form a plane surface of operation, which is horizontal as *a b* on the section *K*, and on this scribe in the bed mould *J,* work off the vertical back joint *c d,* and scribe in the section mould *K*, and work the splay joints *e f* through for wall ribs. Next work the splay joint *g h,* by aid of bevel taken from the section *L,* and scribe in the section mould of ribs, cut ribs in against boss, and complete the mouldings. The boss may be treated as in Fig. 4.

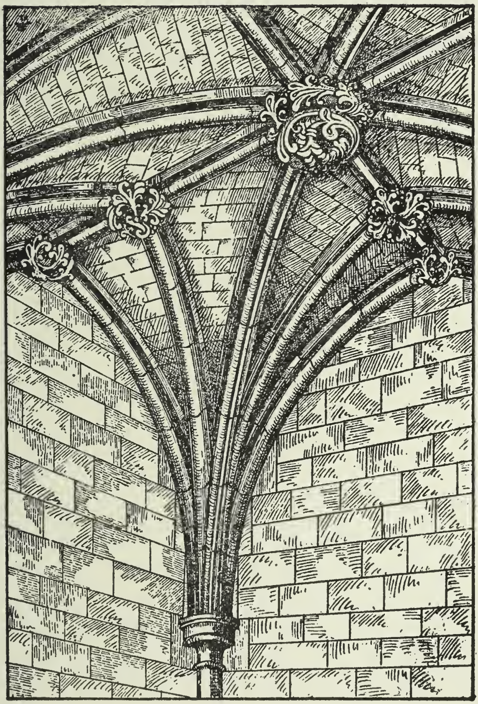
In Fig. 3, at section *A,* the mouldings to ribs are shown, but in the other figures these mouldings are represented by a chamfer, on account of the smallness of the scale to which they are drawn.

On the plan of the springing (Fig. 3), the letters are identical with those at the springing on the smaller scale (Fig. 2), in order that the reference to them may be more clear.

Fig. 7. Shows a sketch of part of the vault.

GROINED VAULTING

FIG. 7



SKETCH OF PART OF VAULT

Fig. 8. The extent to which vaulting of a complicated nature may be carried out is shown in the plan here given of part of the vaulting at the Members' private entrance, House of Commons.

The student may be reminded that the examples here given of groined vaulting deal only with a small portion of this intricate subject, but it is hoped that the general principles have been sufficiently illustrated, so as to enable him to deal with other cases as they come before him.

Plates XXIV, XXV, XXVI, XXVII, XXVIII.

TRACERY WINDOWS.

Tracery Windows are of the most extensive variety, both in design and form, and require no little consideration and study on the part of the student. The correct carrying out of the designs for such works affords valuable evidence of the mason's skill.

Without going into the principles governing the composition and design of tracery, it may be remarked that, with few exceptions, geometrical tracery is based upon the combination of the equilateral triangle with the polygon and circle; and the examples here given will mostly illustrate this particular style.

In setting out tracery windows generally, commence by drawing the vertical centre line of window, then the springing line at right angles to the same, and set off the span, or opening, and draw segment line of the arch. Divide the span for small openings, and draw in the mullions. This may also be obtained from the plan if first drawn. Now draw in the construction lines for centres of tracery to the required design, care being taken that the curves must properly intersect with each other, or be drawn tangental, as the case may be. The mouldings which form the mullion, on taking a curved shape in the tracery, are termed monials.

Gauge on from the centre lines of tracery last drawn the width of monial, giving the lines of nosings, fillets, splays, &c., and complete the window by drawing the foliations, eyes, and cusps.

TRACERY WINDOWS

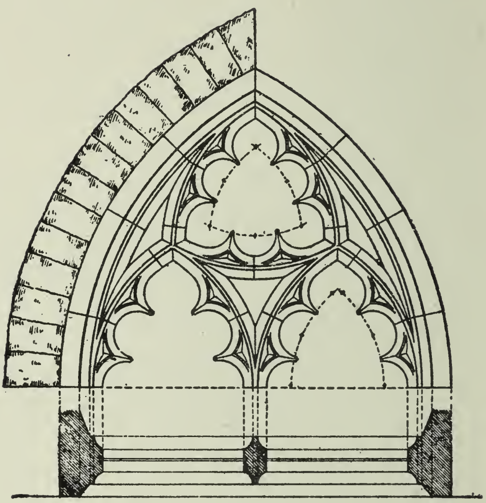


FIG. 2

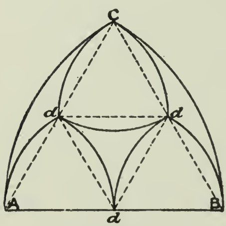


FIG. 1

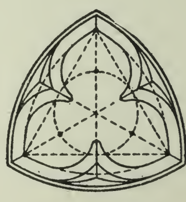
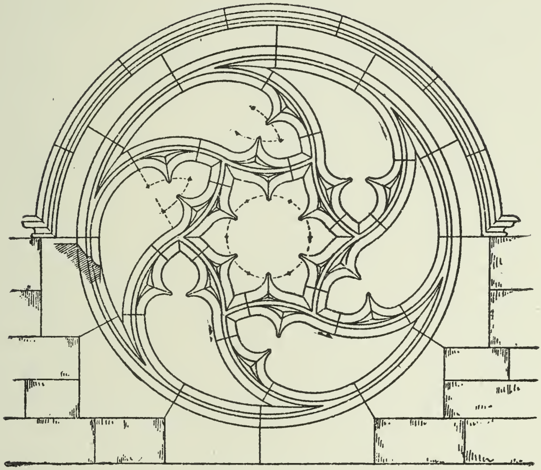


FIG. 3

TRACERY WINDOWS

FIG. 5



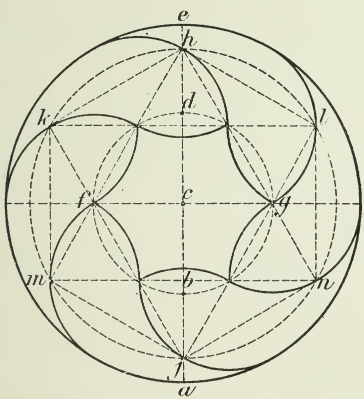


FIG 4

The joints of all tracery windows should be drawn in to radiating lines from the centres, by which the principal curves of monials are drawn; this is not always possible, but the rule should be borne in mind.

For the purpose of making the moulds, one half the window only is necessary to be set out.

Fig. 1. Shows the constructional lines of completed window (Fig. 2). The equilateral triangle *A B C,* divided into four similar figures *d d d,* gives the centres for the tracery. This is again exemplified in Fig. 3, which shows the trefoil, the centres of which are evident, and need no description.

Fig. 4. Shows the constructional lines of circular window (Fig. 5).

To construct the figure, divide the diameter into four equal parts, as *b c d e,* and with *c* as centre and *b* or *d* as radius, describe a circle, and inscribe a regular hexagon, intersecting with the opposite diameter at *f g.* The points of intersection will give one half of the centres of tracery.

On the diameter at *f g,* as a common base, construct the two equilateral triangles *f g h* and *f g j,* and with *c* as centre, and *h* or *j* the apex, as radius, describe a circle, and inscribe the hexagon *h j k l m n,* or produce the equilateral triangles, cutting the circles in these points. These give the other half of the centres, for completing the main lines of tracery.

Fig. 5. Is the completed window, with foliations, eyes, and cusps, and label moulding.

It may be observed, that four face moulds, with a slight modification in two of them, will work all the tracery in this window.

Fig. 6. Shows the elevation and part plan of win-

TRACERY WINDOWS

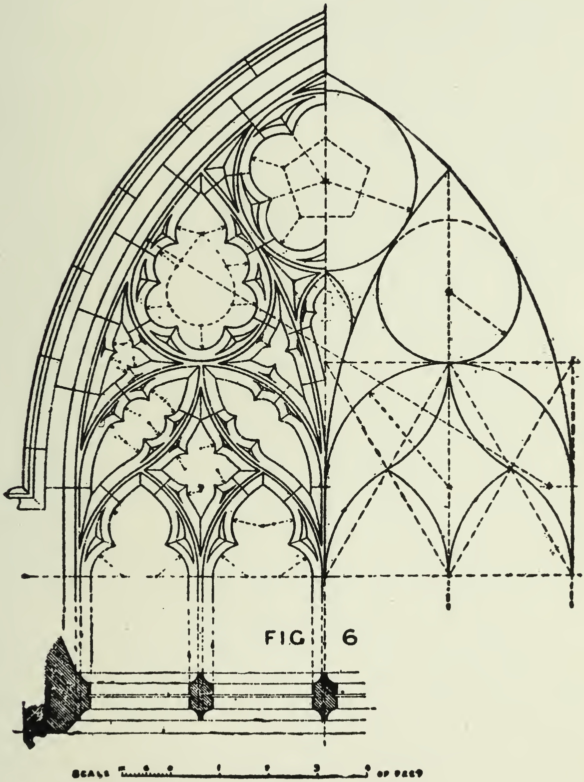


FIG 6

dow, the right-hand half in elevation, showing constructional lines, and the left hand the completed half of window.

This will be understood without further instruction than is afforded by the illustration.

Fig. 7. Shows the elevation and part plan of window, the right-hand half in elevation showing constructional lines, and the left-hand the completed half of window.

The geometrical constructive lines are not so marked or apparent in this window, yet it has a purely geometrical expression, the trefoil and circle predominating.

This example has been chosen to illustrate the working of one of the stones, which is typical of the working of each of the others.

Fig. 8. Shows face mould of the springer *A*, transferred from elevation (Fig. 7). *B B* are section moulds of main monials, *C* is section mould of mullion, or bottom bed, of springer, and *D* is section mould of small monial; this applies to the two branch joints.

To work the springer, commence by working a plane, as a surface of operation, and on this scribe in the face mould *A* marking-in the nosings *a a b* by the aid of a templet, the nosings being the only portion of the plane not cut away. Next point the stone roughly to shade of the face mould, and then take it to a parallel thickness, equal to the thickness of the section mould *B* or *C*. Now work the joints through square from the face, and scribe in joint moulds *B D* and *C* on their respective joints. Then work through the nosing *a a* and *b*, and boutel mouldings, and fillets, and sink down the whole of the remainder of face to lower nosing *c c c*, scribe in on each side of nosing the skeleton face mould (Fig. 9),

TRACERY WINDOWS

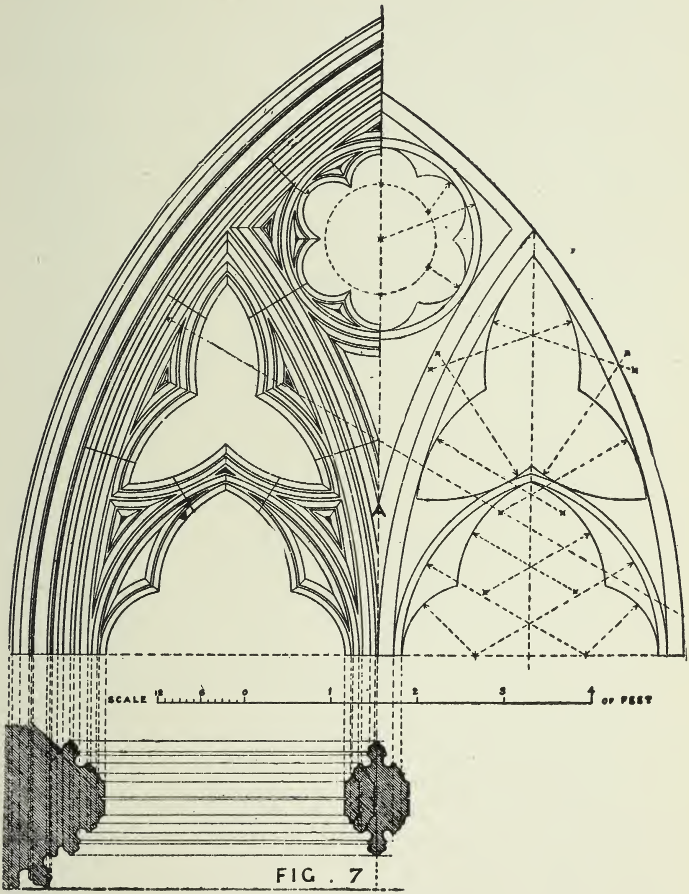


FIG. 7

and work the soffits through to shape. Sinkings are now made for the several mouldings, the eyes of cusps are pierced, and the stone finished to its correct shape, templets and reverses being used in guidance.

Fig. 9. The using of the skeleton mould, here illustrated, saves the working through of the soffits, from the outside, or first surface of operation.

The section moulds for monials, in several cases, will require a little widening out, as at *D*, and these may be projected from the face mould. The reason for this is, that the joints are not always on a true sectional line.

Fig. 10. Shows sketches of various examples of cusps, which require no explanation.

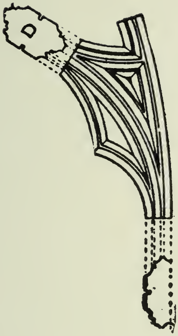


FIG. 9

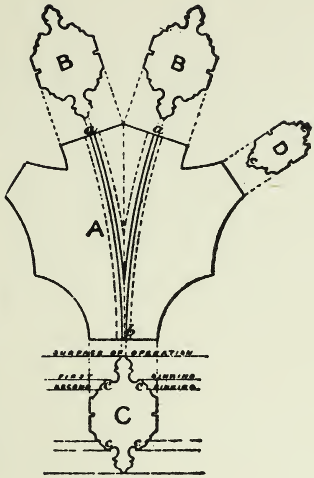
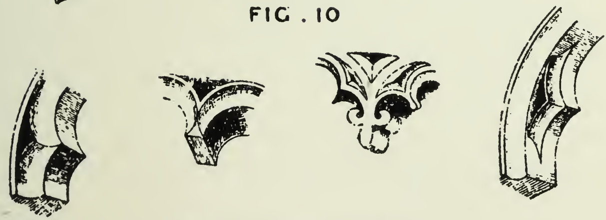


FIG. 8

FIG. 10



SKETCH OF CUSPS

Plates XXIX, XXX, XXXI, XXXII.

GOTHIC MOULDINGS.

The profiles of mouldings here given are indications of the various styles or periods, and are of great interest to the student of Masonry, and also because they attest the working skill of the mason.

The characteristics generally of each period and the dates are briefly as follows:—

Norman, 1066 *to* 1189.

The mouldings consist chiefly of chamfers, round, and quarter round members, with shallow hollows, the edge roll or bead being the principal member. These are frequently entirely covered with ornament, such as the chevron or zigzag, the billet, the lozenge, the double cone, the star, the pellet, and others, producing great richness of effect.

Early English, 1189 *to* 1300.

In this period the mouldings are bold and deeply undercut, and generally arranged on rectangular planes; they are composed chiefly of the bowtel and keel members, with a combination of fillets and deep hollows of irregular curves, resulting in a beautiful effect of light and shade. The curves of these mouldings are easy and graceful, and are usually drawn by hand, the compasses being little used.

The principal ornament of these mouldings is the dog-

tooth, which is greatly varied, and belongs exclusively to this style.

Decorated, 1300 *to* 1377.

The mouldings in this style are bold and well proportioned, and arranged on rectangular as well as diagonal planes. The rounds and hollows are not so deeply cut as in the preceding style, the hollows being segments of circles, the deeper hollows being confined to the inner angles; the roll moulding, the quarter round, and wave mouldings are also very much used in combination of the groups.

The ornament is chiefly the ball flower, of which there are several varieties, and the four-leaved or diaper flower; these are nearly as characteristic of the Decorated style as the tooth ornament is of the Early English.

Perpendicular, 1377 *to* 1547.

This style is characterized by mouldings which have large and shallow members, and generally a large hollow in the centre of each group, and arranged on diagonal planes. Another feature of this style is the constant use of beads of three-quarters of a circle and also flat wave mouldings; to this may be added the absence of fine detail.

The common ornaments are the Tudor flower, rose, and fleur-de-lys cresting, an example of the last-named being given on Plate 32.

Plate XXIX. GOTHIC MOULDINGS.

PROFILES OF GOTHIC MOULDINGS.

Norman Period, 1066 *to* 1189.

1 to 5. Cushion caps of various forms, principally from Peterborough Cathedral.

6 to 14. Bases, various.

15. Base from nave, Workshop Priory.

16. Arch mould from transept, Peterborough.

17. Arch and label mould from nave, Tutbury.

18. Arch and label mould from nave, Southwell.

19. Arch mould from transept, Peterborough.

20. Arch and label from mould nave, Workshop Priory.

21. Arch and label from mould nave, Wenlock Priory.

22. Arch and label from mould transept, Peterborough.

23. Arch and label with various enrichments.

24 to 29. Strings, various.

30. The sunk star ornament.

31. The billet ornament.

32. The square billet ornament.

33. The lozenge ornament.

34. The double cone ornament.

35. The chevron or zigzag.

36. The Beakhead.

1a, 2a. Ornament in caps, Workshop Priory.

NORMAN PERIOD — 1066 TO 1189.

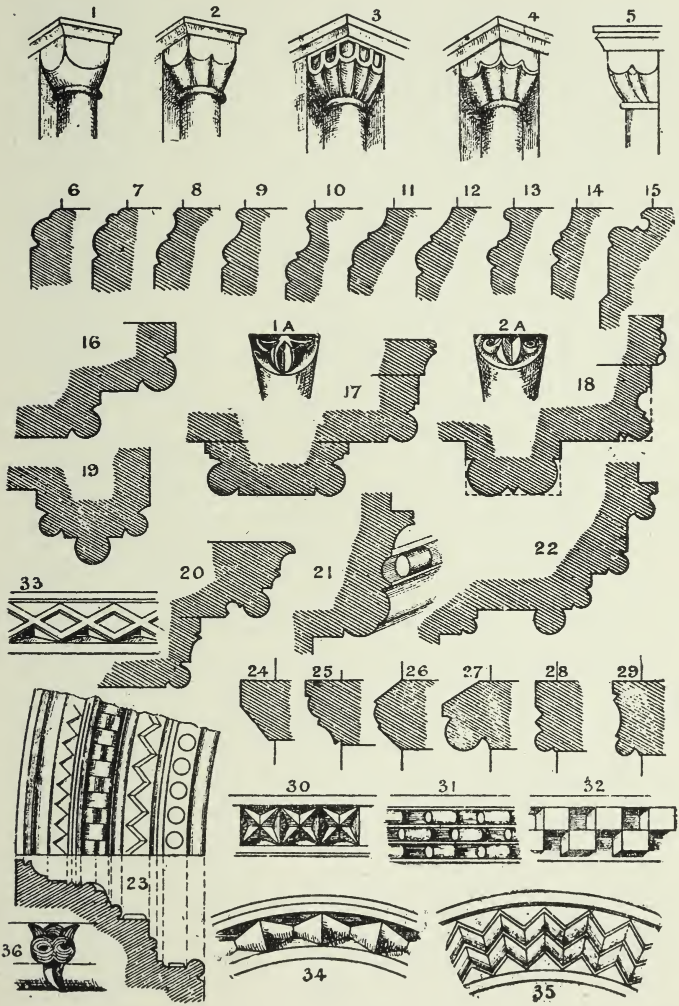
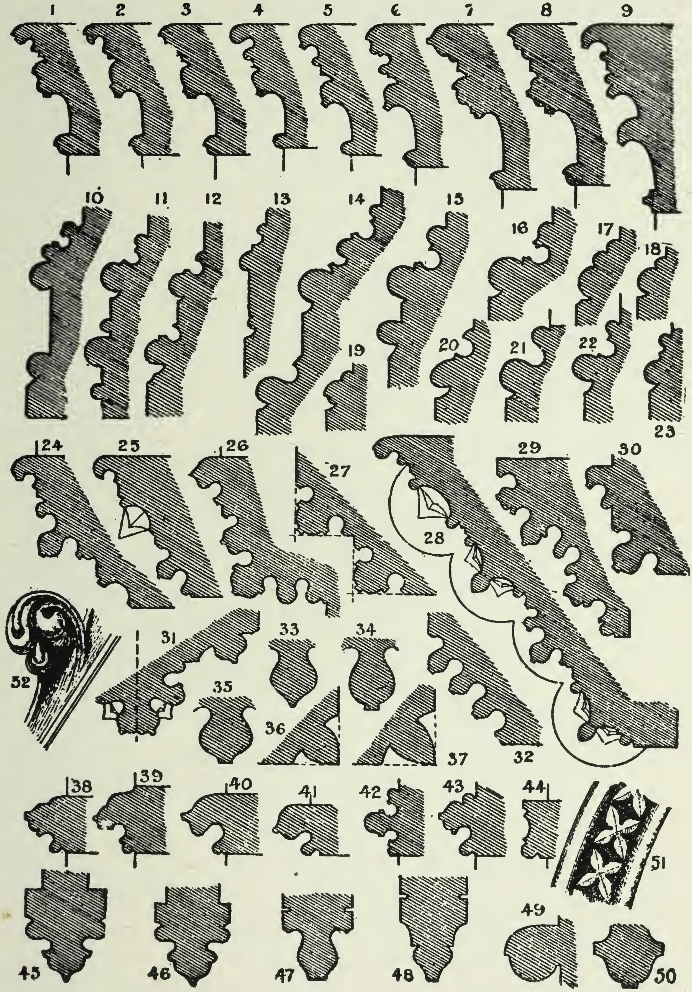


Plate XXX. GOTHIC MOULDINGS.

Early English Period, 1189 *to* 1300.

1, 2, 3. Caps from Westminster Abbey, Triforium.
4 and 6. Caps from Bolton Abbey.
5, 7, 8. Caps, various.
9. Caps from Carlisle Cathedral.
10. Base from Carlisle Cathedral.
11. Base from Ely Cathedral.
12. Base from Peterborough Cathedral.
13. Base from Cowling, Kent
14. Base from Lincoln Cathedral.
15 to 19. Bases, various.
20. Base from Warmington, N. Hants.
21. Base from Durham Cathedral.
22. Base from Lincoln Cathedral, Arcade.
23. Base from Bolton Abbey.
24, 25. Arch and label moulds, Warmington, N. Hants.
26. Arch and label moulds, Carlisle Cathedral.
27. Jamb mould.
28. Arch and label moulds, Warmington, Doorway.
29. Arch mould, Lincoln Cathedral, Arcade.
30. Arch mould, Longham Church, S. Transept.
31. Arch mould, Beaulieu, Hants.
32. Arch mould.
33, 34, 35. Bowtel mouldings.
36, 37. Keel mouldings.
38 to 44. String mouldings, various.

EARLY ENGLISH PERIOD — 1189 TO 1300



45, 46. Rib mouldings.
47, 48. Mullion.
49. Scroll moulding.
50. Roll and triple fillet.
51. Dog-tooth ornament.
52. Crocket ornament.

Plate XXXI. GOTHIC MOULDINGS.

Decorated Period, 1300 *to* 1377.

1. Cap from Irthlingborough.
2 to 8. Caps, various.
9 to 14. Bases, various.
15. Mullion.
16. Jamb mould.
17. Arch mould with ornament of ball flower and four-leaved or diaper flower.
18, 19, 20. Arch and label moulds.
21. Arch mould from Lichfield, Choir.
22. Arch mould from Stafford, Nave.
23. Jamb mould from Holbeach Church, Lincolnshire.
24 to 30. String and label moulds, various.
31. Triple filleted roll.
32 to 35. Varieties of wave mouldings.
36. Ball-flower ornament, three varieties.

DECORATED PERIOD 1300 TO 1377

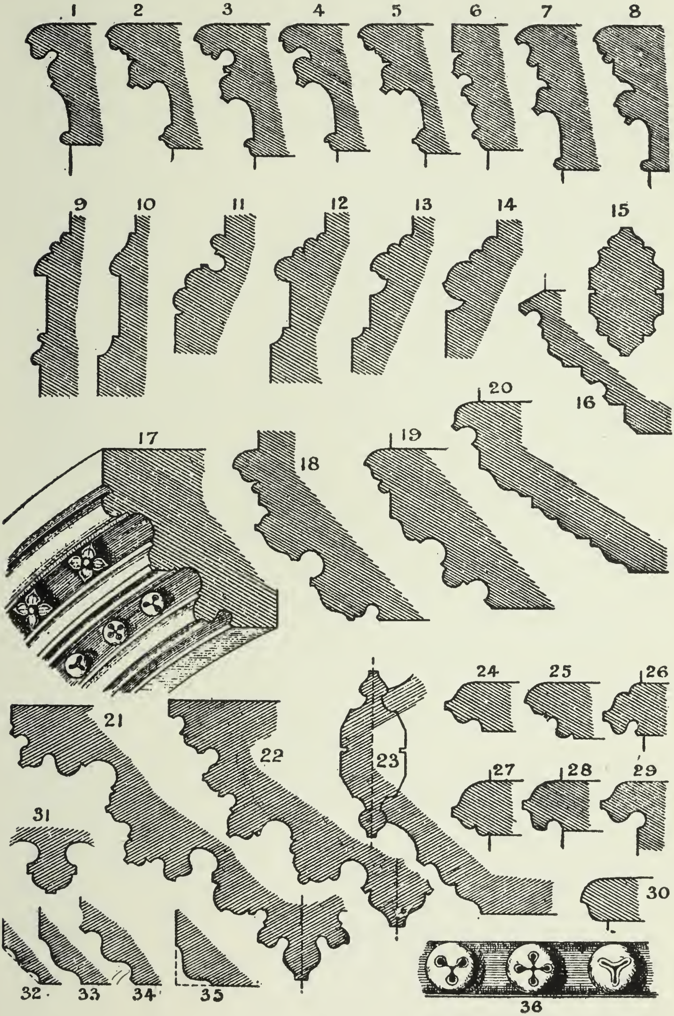


Plate XXXII. GOTHIC MOULDINGS.

Perpendicular Period, 1377 *to* 1547.

1 to 7. Caps, various.

8 to 15. Bases, various.

16. Arch mould and label from Chester Cathedral.

17. Arch mould and label from Newark, Nave.

18. Arch mould and label.

19. Jamb mould.

20. Pier mould from St. Stephen's Cloisters, Westminster.

21. Wave moulding.

22. Wave moulding.

23. Mullion, St. Stephen's Cloisters.

24. Rib moulding, St. Stephen's Cloisters.

25. Buttress moulding.

26 to 33. Strings and labels, various.

34. Sill mould, Christchurch.

35. Cresting ornament.

PERPENDICULAR _ PERIOD _ 1377 TO 1547 _

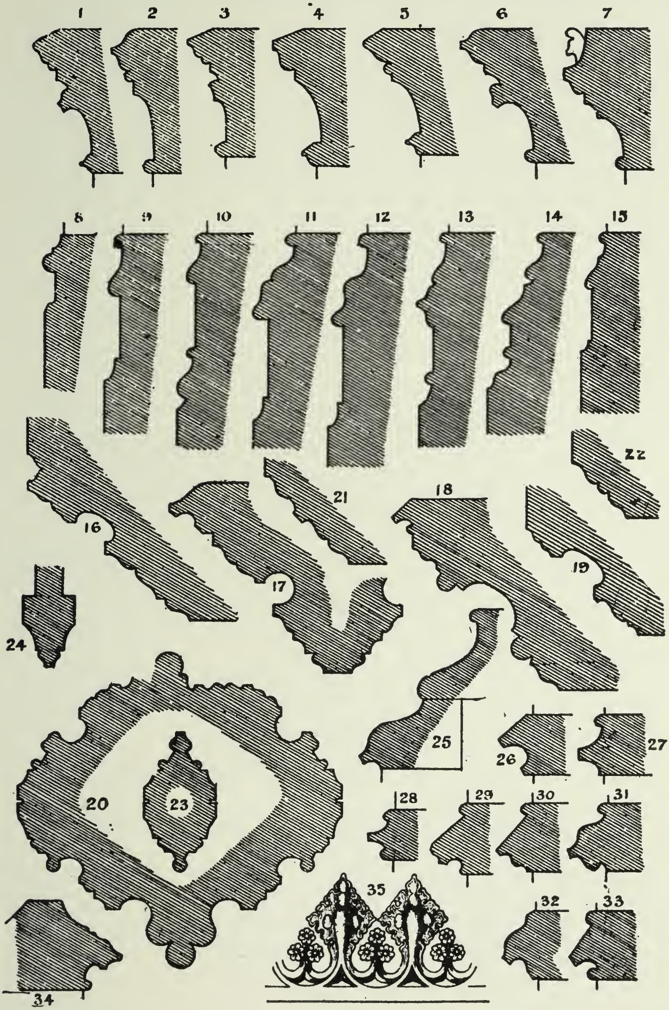


Plate XXXIII. GRECIAN MOULDINGS.

The profiles of these mouldings are composed of lines of varying curvature, and mostly correspond to conic sections, embracing the hyperbola, parabola, and ellipse. It is considered, however, that they were drawn by hand, and not obtained by any mechanical method.

The examples here shown are taken chiefly from the works of Sir William Chambers and Inwood.

1. Section of the Doric cornice from the Parthenon.
2. Plan of external angle of ditto, looking up, showing the mutules and honeysuckle enrichment.
3. Section of Ionic cornice from the Erectheium.
4. Section of Ionic cornice from the Erectheium.
5. Doric cap from Samothrace (Hyperbola).
6. Doric cap from the Theseum (Parabola).
7. Doric cap from Selinus (Ellipse).
8. Ionic base from the Temple on the Ilyssus.
9. Ionic base from Minerva Polias.
10. Ionic base from Prienne.
11. Corinthian base from Monument of Lysicrates.
12. Capital of Antæ from Erectheium.
13. Capital of Antæ from Erectheium.
14. Capital of Antæ from Erectheium.
15. Egg and tongue enrichment.
16. Annulets or neckings to Doris caps.

Note. It may be here observed that the columns of the Greek Doric have no base, but are planted direct on the square step which is a feature of this particular style of building.

GRECIAN MOULDINGS

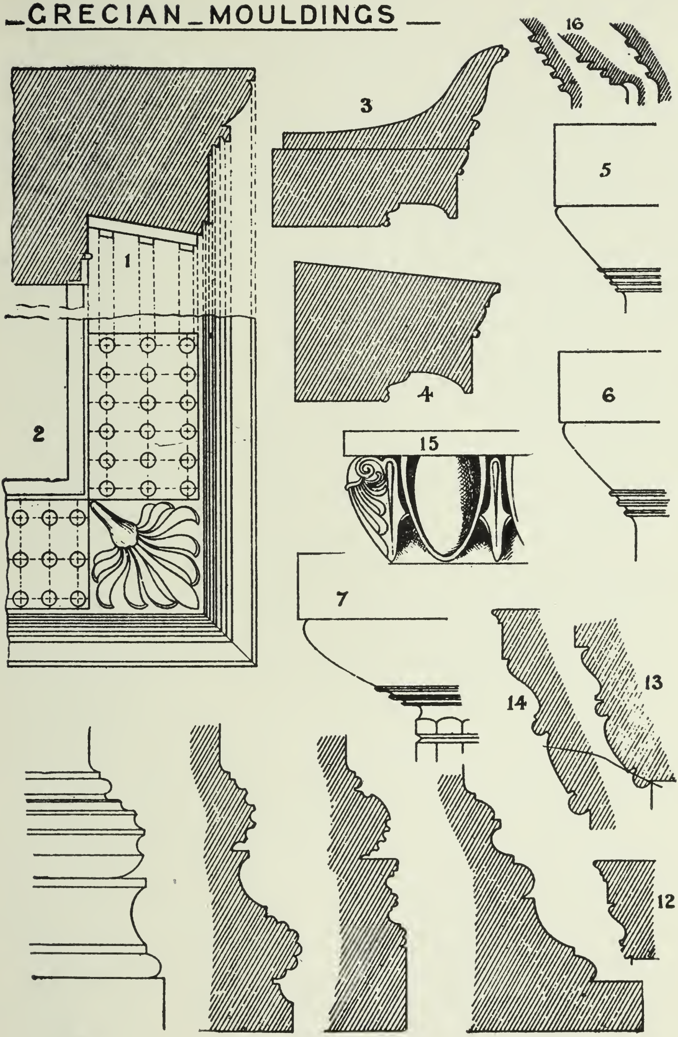
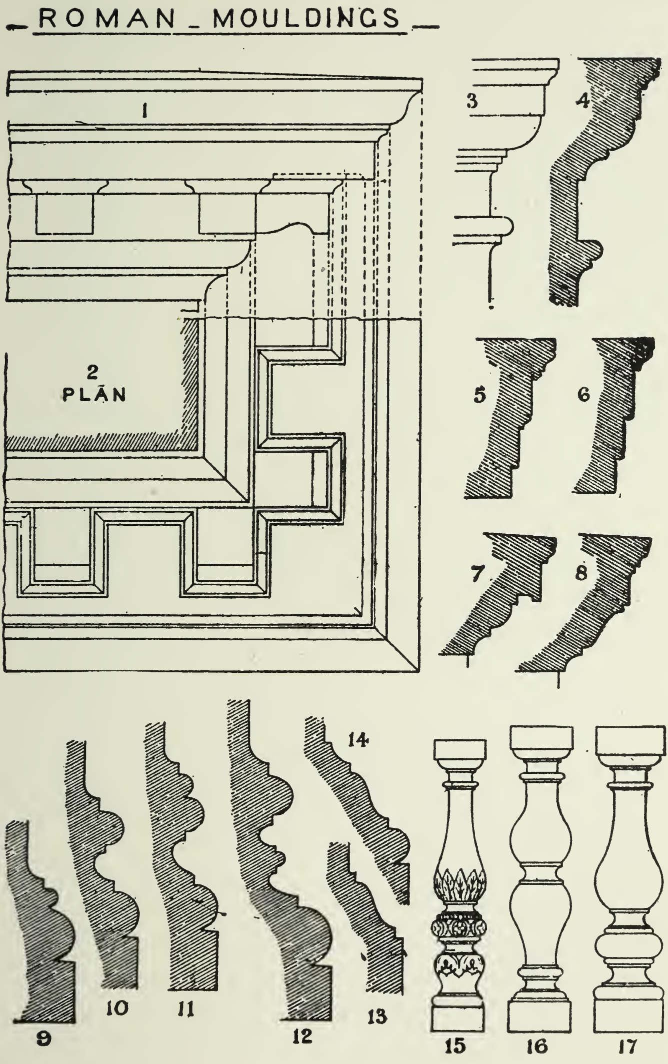


Plate XXXIV. ROMAN MOULDINGS.

These mouldings are all derived from Greek originals, but without their refinement of outline, and in artistic beauty are far below their predecessors. The profiles are in most cases composed of segments of circles.

1. Elevation of Doric cornice.
2. Plan of external angle of ditto, looking up, showing the modillions.
3. Elevation of Doric cap.
4. Section of capping to Doric pedestal.
5. Section of Architrave.
6. Section of Architrave.
7. Section of pedestal capping.
8. Section of pedestal capping.
9. Section of Tuscan base.
10. Section of Doric base.
11. Section of Corinthian base.
12. Section of Composite base.
13. Section of pedestal plinth.
14. Section of pedestal plinth.
15. Baluster (enriched).
16. Baluster.
17. Baluster.


ROMAN MOULDINGS
1
2
PLAN
3
4
5
6
7
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MASONRY ESTIMATING AND QUANTITY SURVEYING.

Estimating. In regard to measuring and estimating the values of masonry, it will be necessary to state, by way of preliminary, a few particulars which are essential to good and sound estimating.

The advantage to the mason in estimating for his own trade is, that he knows the various processes the stone has to go through, together with the different labors. In order to do this in the proper way, he should be well versed in the science of construction as applied to buildings, and competent to read any drawing; and it will be better still if he be also qualified to prepare any detail drawing in connection with the work, as by this means he will be able to discover any particulars that relate to the practical working of the stone, which otherwise might escape his notice. Again, the more thorough the mason is as a draughtsman, the more thorough he is as an estimator.

The first step in connection with estimating, after the drawings have been consulted, is to carefully read and digest the specification, and to ascertain if there is any hidden work which is not shown on the drawings—in other words, where to expect and where to look for all stonework not clearly shown or described. The mason should also know how the stonework butts against the different materials, the various notchings, rebates, &c., against girders, brick, wood, &c.; and in general he should satisfy himself that he understands from the re-

quirements of the drawings and specifications exactly how the stonework should be cut and set in the wall.

Next, but not least, is the mathematical qualification necessary for the mason, which in general is simply arithmetical, although there are times when his knowledge of practical geometry, as well as plane trigonometry, will help him to advantage. Lastly, a neat and methodical way of "taking off quantity" should be cultivated, and also to figure the various items correctly from such data as may be obtained from the shop records of labor, which consist of a series of ascertained values of actual work done. When there is any intricate or new work to which the shop records have no reference, the mason's practical experience and judgment will enable him to determine the values, and thus the approximate cost may be obtained.

It should also be remembered that, to be successful in estimating, it is necessary above all to have order and method, and in the cultivation of these gifts the mason is in the right way of becoming master of the principles of his craft, in this particular branch.

Quantity Surveying. There is perhaps a greater diversity of opinion as to the proper system to be adopted in estimating for stonework than is to be found in any other branch of the building trade. This arises from the fact that masonry generally is in itself very complex, and that no two buildings are alike in style, material, or finish. These differences of systems, however, are being gradually narrowed down by custom and usage, and one might almost say that the only difference—certainly the greatest—is the description of the labor on stonework.

At one time half-sawing was taken on all the six sides of the cube, and any labor expended on these sides or

faces was added; but with the system of measuring being generally adopted, half-sawing is ignored except for the back of the stone built into the wall, it being assumed that all other labors include the price of sawing.

Another method is to take out the stone including labor, and to divide it into a few main items, each composed of stone upon which the labor is similar, and giving sketches to the more ornate parts, as "stone and labor in chamfered jambs"; "ditto in moulded ditto"; "ditto in chamfered plinths, and strings"; "ditto in arcading," &c.

Yet another method, instead of wading through the quantities, is to work out an average block of each kind of work upon the other and more correct system, and reduce the cost thus found to a set of prices "per cubic foot." This is a somewhat haphazard way of estimating, and not to be recommended. It may save time and facilitate progress, but it is equally undeniable that it is as uncertain in results as careless in process.

The method, therefore, adopted here is to measure net the cubical block of stone, and take all the labors upon it separately.

In taking off quantities, it is essential to take them in the following order, viz., length, breadth, and depth (height). This plan will invariably prevent confusion, and it also admits of after-identifications of dimensions if necessary.

In measuring cube stone per foot cube, the stone is measured the net size of a rectangular block, which just encloses the finished stone. When any fraction of an inch occurs, call it another inch, a for instance 1 ft. 4¾ in. by 11½ in. by 9½ in. should be called 1 ft. 5 in. by 1 ft. 0 in. by 10 in.

Add to the price of the stone the labor of setting, hoisting, and scaffolding per foot cube; and so describe.

State in all cases how stonework is finished, whether tooled, chiselled, rubbed, dragged, combed, &c.

If stone is hoisted to a height of 40 ft. it is kept separate, and so stated, and also in heights of 20 ft. above same, as 40 ft. to 60 ft., 60 ft. to 80 ft., &c.

This course is sometimes modified, as when a well-defined line occurs a little under or over the limit; the height, however, should be stated.

All stonework up to 3 in. in thickness is taken by the foot super, and all labors on same described.

If any of the stones are above 6 ft. in length, take the cubical contents and call it scantling.

Beds and Joints per foot super are described as "one face measured for two."

It is usual to take a bed and a joint to each stone, which will be equal to half-bed or joint on four out of the six surfaces of the block—that is, the top, bottom, and two sides. Sometimes beds and joints and preparatory faces are omitted, and the stone described as including all plain beds and joints, and preparatory faces. When this course is adopted every other labor is measured as it finishes.

If the drawings do not indicate the joints, as in cornices, strings, plinths, capping, &c., take a joint to every 3 ft. in length.

An average of beds and joints to each cubic foot of stone is in Modern Classic 1½ ft. super; Gothic, 2 ft. super.

The labor to back of stone is generally described as half-sawn or drafted and measured by the foot super.

Sunk Beds and Joints per foot super, described as "all measured," are taken to all beds and joints, when sunk below the general surface.

Circular Beds and Joints per foot super, described as "all measured," are taken to all beds and joints, when sunk below the general surface, as in arch stones, and may be either concave or convex. The extrados and intrados of an ordinary arch are an illustration.

Circular Sunk Joint per foot super, described as "all measured." These are joints sunk below the circular face, as in the reveals and rebates of arches; when stopped, state so and keep it separate.

Plain Face or Plain Work per foot super. When dressed to an even finished surface, either tooled, rubbed, or dragged as may be required; this includes also preparatory faces, as to tracery windows, &c.

Sunk Face per foot super, taken to all faces below the general surface, as in panels, weatherings, &c. When the sinking cannot be worked straight through the stone it is called "Sunk face stopped."

Sunk face not exceeding 3 in. wide is measured per foot run and the width stated.

Rough Sunk Face per foot super is taken to the general surface of all mouldings over 3 in. below the general surface.

Circular Face per foot super, and describe as "all measured," is taken to surfaces that are convex, as in shafts of columns, &c.; state if stopped, and keep separate.

Circular Face Sunk per foot super, and describe as "all measured," to all surfaces that are concave, such as soffits of arches, &c.; state if stopped, and keep separate.

Circular Circular Face per foot super, and describe as "all measured," to all surfaces that are circular on plan and elevation, such as convex surfaces of domes, spheres, &c.; state if stopped, and keep separate.

Circular Circular Face Sunk per foot super, and describe as "all measured," to the concave surfaces of domes or niche heads; state if stopped, and keep separate.

Moulded Work per foot super, and describe as "all measured"; taken to the profiles of all mouldings in strings, cornices, caps, and bases, &c. Girth the mouldings to get at the superficial area.

Mouldings not exceeding 6 in. in girth, measure per foot run and state girth. Mitres in mouldings to be numbered; these are sometimes taken (for pricing) as equal 1 ft. run of the moulding to which they belong.

Where mitres occur in mouldings, measure to the extreme length of the nosing for running length.

Mouldings not exceeding 9 in. in length, take as short lengths and keep separate.

Stopped Ends, numbered, stating girth of moulding.

Ashlar is sometimes measured per foot super; state average thickness and how the face is finished, whether rubbed, tooled, chiselled, or dragged; if bond stones state their size, the proportion of bond stones to the area of wall face, also that the ashlar includes all labors to beds and joints. When backed up by brickwork, state it, and keep brickwork separate and describe as extra only in backing to stone ashlar.

The other method is to measure the stone by foot cube, and all labors separately per foot super, as before described.

Boasting, per foot super, where over 6 in. girth. This is the preparatory or rough dressing in outline for carving.

Carving. The value of this so much depends upon the ornate quality of the work, that it is usual to obtain an estimate from the carver.

Measure spandrel steps (when two are cut out of one block) the extreme width from the nose of the tread to the acute end of the angle by half the riser, taking from top of tread (front of nosing) to the acute end of angle downward.

When the stooling is left on the end for pinning into the wall, the steps must be measured solid.

Measure winders the extreme length, including the wall hold, by the mean width and by the whole height.

The labor to spandrel steps may be taken as plain work to tread and soffit, sunk moulded work to riser and quoin per foot super, rebates (front and back) at per foot run, mitres numbered.

When the soffits are moulded the girth must be taken, and described as sunk moulded work.

The soffit of winders to be taken as circular sunk face.

Dandings per foot super; measure the length and the width, adding the bearing on the walls; state the thickness and whether tooled or rubbed on one or both sides; measure the cutting and pinning into walls by the foot run; if above 30 ft. super in one stone state such, and keep separate, being more valuable.

Window Sills per foot run; measure the lengths, giving the width and thickness; state if quarry-worked, tooled, rubbed, or sunk, and if throated.

Coping per foot run; collect the lengths; state the thickness and width, and whether tooled or rubbed, if parallel, feather-edged or saddle back, and if throated; also if bedded in mortar or cement.

Curbs per foot run; measure the lengths, state the size and how worked; number all mortises for iron railing and standards, giving the size and depth.

Dentils to cornices, numbered, with the sizes and spaces

between each; state whether fixed in a level or raking line; number the enriched pendants to angle dentils, giving the sizes, with sketch.

Balusters moulded, numbered, give size, description, and sketch; state if turned or worked square; number the mortises, with sizes and depths.

Consoles, numbered, give proper description of the moulded front, caps, &c.; state the enrichments, give the size and sketch.

Capitals to pilasters and columns (carved), to be numbered; give the sizes with full description of the moulded and enriched parts, and sketch.

Rebate, or moulding not exceeding 6 in. girth, per foot run.

Throat per foot run.

Joggles, state what kind, per foot run.

Chamfer, not exceeding 3 in. wide, per foot run.

Groove for flashings, per foot run.

Groove for lead lights, and pointing in cement on both sides, per foot run.

Holes and perforations, numbered, stating size and thickness of stones.

Mortises and Dowels, numbered, and state if copper, gun-metal, lead, iron or pebble dowels, and if run in cement, or sulphur, &c.

Cramps, numbered; state if in copper, gun-metal, slate, or iron; give size and weight.

Chimney-pieces. Usually a provisional sum is allowed, otherwise they are numbered, stating size of opening, width of jambs and shelf, and how finished, if flat or boxed, and whether stone or marble.

BUILDING STONES.

The importance of choosing a good building stone for durability is well known, but unfortunately too little attention is generally given to the selection of the stone in order to obtain a perfect structure. Yet, however careful the selection may be, it should be borne in mind that there are no stones of any kind, whether they are the hardest and most intractable of the syenites or granite, or the softest lime or sandstone, that are not perishable in a greater or lesser degree in the course of time.

The physical forces and agencies, within and without, which produce this effect are apparently invisible, although always present, each working in its own way, with the same result, that the stones begin to disintegrate and gradually fall away into dust.

A high authority has observed that "in modern Europe, and particularly in Great Britain, there is scarcely a public building of recent date which will be in existence a thousand years hence. Many of the most splendid works of modern architecture are hastening to decay in what may be justly called the infancy of their existence, if compared with the dates of public buildings that remain in Italy, in Greece, in Egypt, and the East."

Should this be true, it is a serious outlook, and it is therefore obvious that the mason should have a full and accurate knowledge of the general structure of rocks, as well as of the situations where the best materials may be obtained, the composition of the stone he uses, and the destructive agencies that it will have to face, so as to

direct his choice in the selection of particular stones, and enable him to estimate the advantages to be gained from their proper application for building purposes.

He should also know whether the material is good or poor, whether it is perfectly adapted for the particular work he has in hand, how it should be handled to produce the best results and fulfill the conditions of economy, utility and good workmanship.

It should not be forgotten that a bad selection of stone cannot be rectified when once used in a building, and is a lasting testimony to want of care and experience, and that a good selection remains a permanent record for posterity.

In order to identify a good stone, the mason must use his powers of observation. Examine carefully a building which has stood the wear of time, and which is subjected to a similar atmosphere to that of the proposed new building; note its general appearance and its condition as to soundness; should tool marks be visible, they can generally be accepted as a good sign.

Next find out where the stone was quarried, examine carefully the various beds in the quarry, and from what stratum the stone has been obtained; note the weathering of exposed surfaces in the older portion of the quarry, and learn which part is liable to decay first, and the conditions under which it does so.

Take every precaution to ensure getting the stone from a sound and compact bed, and one that is easily wrought and convertible.

It should, however, be recollected that most building stones last longest in the particular locality in which they are found; and that the same quality of stone which stands well externally in the neighborhood of the quarry,

ofttimes goes rapidly to decay when fixed in another part of the country.

Chemical tests and analyses, to determine the quality of a building stone for durability, are admitted by practical men to be somewhat unreliable. The processes which are successful in the laboratory of the chemist are generally of little value when brought into practical use; for chemical analysis will only give the constituents, and microscopical analysis the physical construction of a stone; and neither has as yet been proved to have any direct relation to its weathering quality.

And although stones have been subjected to severe tests in the laboratory—such as being dissolved in various acids, saturated with salts, ground into semi-transparent discs, disintegrated, pulverized, baked and boiled, and treated in various other fashions—yet none of these processes have as yet furnished sufficient data by which a correct judgment or estimate can be formed as to the weathering properties of any stone.

In the foregoing remarks there is no wish to depreciate or disparage the true value of tests by chemical analysis, but rather the contrary. These, however, should be confined to ascertaining the constituent or component parts of the stone; its cementing material; the absorption of water, which gives a fair indication of the power of a stone to resist rain and frost; the subjecting of the stone to a freezing temperature and ascertaining the weight lost from the sample; the microscopic test, which is useful in determining the homogeneity of its structure, and others.

With regard to the crushing strength of stone, this is always in excess of requirements, and is to be considered as unimportant.

It should, however, be stated that there is no detail in connection with stone that the mason should not be familiar with. By this means he will be able to remedy defects in existing work, suggest improvements, and build to greater advantage for the future.

The following characteristics are therefore important to be remembered and weighed in the choice of a building stone:

Weathering properties.
Seasoning.
Appearance.
Porosity and absorption.
Natural bed.
Facility for working.
Compactness and weight.
Agents of destruction.

WEATHERING. The weathering power of a stone is dependent upon its physical structure, its composition and the nature of the atmosphere in which it is placed. The most destructive agent that the stone has to contend against is rain, or a moist atmosphere.

The air of towns is charged in a greater or lesser degree with carbonic acid, and in manufacturing towns it also contains quantities of hydrochloric and sulphuric acids. These acids are dissolved by the rain, which penetrates the stone more or less according to its physical structure, and combines with the constituents of the stone, causing it to ultimately crumble away.

A stone which may be sufficiently durable when laid beneath water, as in piers of bridges, docks, quay walls, &c., may not be so when kept alternately wet and dry by the rise and fall of the tide, or when wholly exposed to the action of the atmosphere. A somewhat porous sand-

stone, for instance, may do well when kept constantly under water; but the same stone when exposed to the weather, more particularly in a climate subject to frost, might disintegrate and crumble away.

Stones which are formed of particles of sand cemented together by different substances, the cementing matter being sometimes silicious, at others calcareous, and at others, again, formed of oxide of iron—each of these weathers in a different way. In the first case, the stone would not materially suffer from the chemical action of atmospheric influences upon it; while in the second, rain-water containing carbonic acid would tend to dissolve the calcareous matter, and deprive the sand of its cement; and in the third, the action of atmospheric influences would tend to render the material unsightly by staining it with iron rust.

Buildings having their face exposed to the prevailing (south-west) winds and rain are generally those in which signs of decay to any extent first appear; also the parts that are in the shade, such as the bed mould of cornices, underside of strings, sills, &c. These seldom get the wet dried out of them, and consequently decay first.

Seasoning. Stones are often valued because they are easily wrought when first taken from the quarry, and subsequently become harder when exposed to the atmosphere; and this quality arises from the chemical change which takes place on the evaporation of the water contained in the stone when forming part of the natural rock.

The old masons—and "there were giants in those days"—were very particular about the seasoning of the rough stone blocks before using, and each block as it came from the quarry was placed under cover from the rain, and in-

stead of being laid flat on the ground, was tilted up or inclined upon one of its corners to enable the quarry sap to drain out. Its position also allowed a free access of air to play round the block, which facilitated its drying. This process was carefully watched, and if any latent defect appeared during the drying the block was rejected.

The operation of seasoning the stone took several months before any work could be commenced upon or with it, and it is admitted that this method would add to the cost; but, on the other hand, it is believed that the money would be well spent if this precaution should prevent the wasting of such stones by atmospheric influences, which soon act on the surface of a newly-quarried stone.

Again, stone that is quarried one day and built into the wall the next is in a "green" state, and is not in condition. It is at its weakest; its pores are open, and ready to absorb not only moisture but deleterious agents which tend to its destruction.

It is well known to every mason that work on a stone that has lain by for some time is very different from what is obtained on one fresh from the quarry, the former being the hardest and toughest, a fact which of itself is regarded as sufficient evidence to warrant the course recommended—namely, to thoroughly season the stone before using.

Appearance. The stone which holds its color best will, as a rule, be the most desirable to use, and this feature is also a good guide as to its durability. The value of a good color or combination of colors is well known, and a judicious placing of each color where its particular qualities will best serve the design produces a pleasing effect in a building. The colors to choose from are very

numerous, and in all gradations, and a discreet choice of these will give a general effectiveness of appearance when the structure in which they are utilized has been completed.

Porosity and Absorption. All stones are porous more or less, and those which readily absorb moisture should not be used for the external exposed portion of public buildings, as when frosts occur the freezing of the water on the wet surface continually peels off the latter, and eventually destroys the ornamental and carved work upon it.

This, however, is not a universal rule, as although a stone may be very porous and absorbent, it may also be extremely durable; its durability depending upon the cementing substance which holds the grains together being strong enough to resist the physical forces acting upon the stone, such as the rain, frost, and wind.

The wind in some instances acts deleteriously, as when it drives the rain with more or less force into the pores of the stone, and again when it carries away loose particles which have been dislodged by other means; but, on the whole, the effect of the action of the wind is to enhance the durability of the stone by drying out the moisture and thus assisting its lasting powers.

Natural Bed. All worked stones, with few exceptions, should be fixed on their natural bed—that is, as near as possible to the position they held before being quarried—for set in this manner they are most durable.

In arches, the bed or (what is the same in effect) the laminæ of the stone should be at right angles to the thrust, or as near as may be parallel to the radiating joints of the arch stones. For cornices, the stones are better edge-bedded, except the quoin blocks, which

should be specially-selected stones and laid on their natural bed.

The laminæ of the stone are in some cases so obvious, that the natural bed is easily determined; in other instances, a good deal of practical experience is required to determine the way of the bed. In the oolitic series, small shells are sometimes visible, and faint streaks of earthy matter; these should always be parallel to the bed, and are seen better when the stone is wetted, but it requires an observant eye to detect them. In the absence of these marks, the mason is often guided by the free working of the stone.

Facility for Working. This is an important factor as regards cost, some stones being so hard, and therefore so difficult to cut and dress, that it hardly pays to quarry them for building purposes. Where ornamental work—such as fine mouldings or carvings—is required, a compact stone of even grain should be selected, free from flaws, shakes, vents, clay holes, &c., so that it may be converted with readiness into the various shapes required.

Compactness and Weight. As a rule, the more consolidated the grains or particles composing the stone, the longer will it resist detrimental atmospheric conditions.

The weight of a stone has to be at times considered, and should be such as to suit the work to be carried out. In quay walls, piers of bridges, buttresses, &c., it is advisable to use heavy stones, as their weight adds to their stability; while for the filling-in of panels in vaulting, and similar work, lighter stones are preferable.

Agents which Destroy Stones. These are chemical agents, consisting of acids, &c., in the atmosphere, and physical agents, such as rain, frost, wind, dust, &c.

Other enemies are worms or molluscs, which may just

be noticed here. The Pholas dactylus is a boring mollusc found in the sea, which attacks limestones and sandstones, however hard, with great vigor. It bores holes close together, of various sizes and depths, which so weaken the stonework that it is ultimately destroyed. The Saxicava is another small boring mollusc, which bores holes six inches deep in hard limestones. The only way to resist their attacks is to case the work with granite, which successfully withstands them.

CLASSIFICATION OF STONES.

According to geologists, all rocks from which building stones are obtained may be primarily divided into two great classes—viz., aqueous rocks, formed by the agency of water; and igneous rocks, formed by the action of subterranean heat. There is also a sub-class—viz., metamorphic rocks, including either of the above classes—which, originally stratified, or aqueous, have since been changed in their texture by great heat or pressure.

Aqueous rocks constitute by far the greater proportion of the rocks of the earth's crust, and comprise most of the limestones and sandstones in common use for building purposes.

These aqueous rocks are also termed stratified or sedimentary rocks, owing to the nature of their formation; that is, their particles were once held in solution in water, and gradually sank to the bottom of the sea or a lake, and in process of time became solidified, afterwards making their appearance on the surface of the earth by reason of upheavals and disruptions thereof.

Igneous rocks form a much smaller portion of the earth's crust than the aqueous rocks, and are of volcanic origin; they appear to be formed by fusions due to intense heat, generated by chemical action in the bowels of the earth. Hence the stones in this class are as a rule extremely hard; they comprise the granites, traps, and syenites, some of which are quite unworkable.

GRANITES, TRAPS AND SYENITES.

Granite is the rock most commonly met with in this class. Its component parts consist of quartz, felspar, and mica. The first of these is practically indestructible, and when largely present renders the stone extremely hard.

The quartz is in the form of clear, colorless, or gray crystals, and is easily recognized, being not unlike fragments of glass, and is pure silica. It surrounds the other ingredients like a wrapper, the felspar and mica being embedded in it.

The felspar is in compact, opaque grains or crystals of a white or flesh color, and is the predominant constituent and usually the first to show signs of decay. The mica is in small, white, silvery scales, easily removable with the point of a knife, and capable when large enough of being bent.

Granite usually contains more of felspar than of quartz, and more of quartz than of mica; and the color of the granite is influenced to some extent by that of the principal ingredient.

The best quality of granite is considered to be that in which the grains or particles are fine, uniform in size, and lustrous, and equally distributed throughout the whole mass, its durability depending upon the quantity of its quartz, and upon the nature of its felspar, whether containing potash or soda; potash felspar being more liable to decay than soda felspar.

Syenite granite is tougher and more compact than the ordinary granite, but is less commonly found, and owing to its color and intractable qualities in working is not often used. In syenitic granite the mica is replaced by

hornblende, which is in black or dark green grains; it is easily distinguished from mica by the scales not separating so freely; these also are brittle instead of elastic, and sometimes have a fibrous appearance.

Granite is one of the most valuable of building stones, owing to its great strength, hardness, and compact texture, which renders it able to resist in a high degree the action of wind and rain, and other physical agencies surrounding it. A great amount of labor, however, is required to cut and bring it to a high finish, hence it is only used in building for special purposes, and in good monumental work. It is found in various gradations of color, and great variety of texture and composition, and takes a high and permanent polish.

Porphyry, owing to its granular structure and extreme hardness, is little used for building or ornamental purposes, and is almost, if not quite, unworkable. It is incapable of being raised in large blocks, and is principally used for road metalling, for which its hardness and toughness render it specially suitable.

The ancients are believed to have been in possession of some secret of preparing bronze tools, which were capable of acting upon this intractable material, and carving in it with facility their colossal statues, obelisks, &c., which remain to this day monuments of their skill in the use of the chisel. And it is very humiliating to think that, with all our modern scientific knowledge and extended manipulation of metals, we cannot produce steel or other tools sufficiently hardened to successfully attack and work this beautiful material.

Trap rocks comprise basalts and greenstones, which occur in dykes, sheets, or other eruptive masses of volcanic origin, and are sometimes stratified and sometimes

columnar. These rocks are of a dense and compact texture, extremely hard and tough, and are seldom used in building. The color is too sombre, being of a dark green inclined to black, but the stone is much used for kerbs, paving, road metalling, &c. Basalt, which occurs in columnar form, is seen at the Giant's Causeway, Ireland, and Fingal's Cave, Staffa. It is composed of several minerals—felspar, augite, magnetic iron, &c.; these, however, can rarely be detected by the eye alone.

Greenstones show larger crystals, are heavier than granite, but not so durable, owing to their containing more of the bases of iron, lime, &c., and much less silica.

SANDSTONES.

Sandstones are sedimentary rocks, which have been deposited by the action of water. They consist generally of grains of sand cemented together by different substances—such as carbonate of lime, carbonate of magnesia, silica, alumina, oxide of iron—or a combination of those substances.

In a good building stone very little lime should be present as a cementing material, it being the first to give way under atmospheric influences. The cementing property of the stone, to be of an enduring nature, should therefore be silicious. The general characteristics of a good sandstone are that the grains should be compact and homogeneous, and on crushing a bit of the stone the grains should be lustrous, as those with a dull lustre are generally found in a stone that weathers indifferently. Sandstones with large angular grains are termed gritstones, and the most compact of these are used for grindstones and similar purposes. Sandstones often exhibit distinct beds of stratification along which they have a

tendency to split. A good example of this is seen in paving slabs in which the planes of cleavage are strongly defined.

LIMESTONES.

Limestones are also sedimentary rocks that have been deposited by the action of water; they are composed largely of carbonate of lime, cemented together by the same substance, or by some mixture of carbonate of lime with silica or alumina. They belong to what is termed the calcareous series of rocks, which also include the chalks (the purest form of limestone) and marbles which are crystalline and take a high polish. Limestones usually contain fossil remains, both animal and vegetable.

Portland and Bath stone are the best known of the group which are used for structural purposes, and belong to the oolitic series. Oolite is composed of small round grains, which in appearance resembles the roe of a fish, and on that account is sometimes termed Roestone. When the grains are flat and as large as peas it gets the name of Pisolite, or pea grit.

Siliciferous limestones, which also belong to the oolitic series, have excellent weathering qualities, owing to the siliciferous nature of the cementing material which binds the particles of the stone.

Magnesian limestones contain carbonate of lime, carbonate of magnesia, and a small quantity of silica and alumina, and are termed dolomites. They are more or less crystalline in their nature, the crystals being small and compact.

MARBLES—FOREIGN.

Marble is a general term given to any hard and compact limestone capable of taking a fine polish. It is found in all great limestone formations, and consists chiefly of

pure carbonate of lime in a state of crystallization. The various colors are derived principally from metallic oxides, which give the marble a handsome appearance, much enhanced by polishing.

The Continent supply us with large quantities of marble, plain and decorative, much varied in character, and embracing a vast range of color.

The chief supplies are obtained from Italy, France and Belgium; lesser supplies are from Switzerland, Spain, Portugal, and also recently from Africa.

The celebrated Carrara quarries in Tuscany, Italy, furnish us with the most important marbles; of these, Sicilian is the most useful. The term "Sicilian" is purely English, and is of doubtful origin: it is, however, a misnomer, as it does not come from Sicily; it is supposed to have obtained its derivation from being in its early days shipped from Leghorn to Sicily, and thence re-shipped to England.

It is known in Italy as Ravaccione, or Bianco Chiaro; in France, Blanc Clair; and in America as Ordinary.

Sicilian marble is of a bluish-white ground, mottled with darker shades of gray; it is used perhaps more than any other kind of marble for works of general utility. It is admirably adapted for monumental purposes, columns, statues, vases, stairs, wall linings, baths, chimney-pieces, &c. All the varieties of Carrara marble, when used externally in this country, have perishable qualities; and it has been noticed that after exposure to the weather for thirty or forty years a gradual disintegration of the surface has taken place.

When used out of doors, the marble with slightly bluish tint and of uniform color should be selected, this being the hardest and toughest, and better able to withstand atmospheric influences.

Statuary marble is the most beautiful of all marbles, and is from the same Carrara quarries; it is probably the purest limestone in existence, very crystalline in its structure, and of a fine and compact texture. As its name implies, it is almost exclusively used for the higher departments of sculptural art, for which it is so well adapted, such as statues, groups, monuments, and ornamental enrichments where delicate and refined treatment is required.

This marble is considerably varied in character, the best blocks being of a perfectly white color throughout; these are much sought after, but are only occasionally found quite pure, and then command high prices.

Cloudy markings and spots of a bluish-gray color in the blocks are defects, which must be avoided in sculpture work, hence its costliness.

Bastard Statuary is the name given to blocks having colored markings; these blocks when hard in texture are of good commercial value, and make up well into chimney-pieces, tablets, &c., and take a high polish.

Vein marble is another of the varieties of Carrara; it is of much whiter ground than the Sicilian, and is marked with dark pencil-tinted veins. It is more or less valuable according to the regularity and fineness of its veinings. It is used chiefly in internal decoration, for stairs, chimney-pieces, wall linings, table tops, &c.

This marble was formerly in much request on account of its appearance, adaptation, and easy working; latterly, however, the demand has somewhat diminished, having been to some extent superseded by the Sicilian marble, which has been previously described.

Bardilla is a very chaste and quiet-looking marble, and is one of the Carrara series. It is of a bluish-gray

ground, with numerous black veins running through it in all directions. It was at one time much used for chimney-pieces and decorative work generally, but latterly has got out of date, and made way for newer marbles.

Dove marble, as its name indicates, is of a dark bluish-gray color, with lighter marks or cloudings over its surface; sometimes it has a lighter ground with faint dark marks or veins. This marble was chiefly used for chimney-pieces, &c., but is now for a time out of fashion.

This marble also is one of the Carrara series.

Pavonazzo is a new, and now well-known, marble. It is raised near Carrara. It is of a very rich color, the ground varying from a creamy-white to a yellowish-brown, with veinings of purple, and here and there a greenish tinge, which much enhances its value. It is much used for wall linings, where it is seen to great advantage on account of its markings, and also for chimney-pieces, table tops, &c. It has only been of recent years introduced into this country, but has taken well, and is in much request for decorative purposes.

The above enumeration includes most of the varieties of marble that are found in the extensive quarries at Carrara, but in other parts of Italy are raised colored marbles of great beauty; the names of a few are here given.

Black and Gold is a very handsome black marble with yellow veins. The veining is very beautiful, running from white through every gradation of yellow to light brown, the pencillings being very delicate. It is not so much in use now as formerly, having gone out of fashion, but it is still used to a considerable extent in good buildings for chimney-pieces, pedestals, table tops, &c.; its dark color forms an admirable contrast to sculptured

figures in statuary, alabaster, or other light-colored objects of art.

Genoa Green, which takes its name from the town it indicates, is a handsome marble: its ground is dark green in color, filled with veinings of a lighter green and white; it is used for pilasters, chimney-pieces, and wall surface decoration, for which it is much adapted.

It is frequently sawn up into veneer when a specially good figured block is obtained.

Sienna is quarried near the town of that name. It is of a rich golden-yellow color, with purple and black veins beautifully interspersed. On account of its scarcity, it is difficult to obtain the deep-colored blocks, except on payment of a very high price, and it is stated that the best figured blocks are sold by weight.

It is a most beautiful marble for all decorative purposes.

Egyptian Green. This marble has a darkish green ground with spots of gray and occasionally of white. Another variety has a red ground with clear dark green veins and a network of white lines. These marbles are very choice; they are somewhat difficult to work, but look well and take a good polish.

Both marbles are quarried in the neighborhood of Carrara.

Rhondona, a marble quarried at Mount Rhondona, Tuscany, has a ground of pale pinkish-white, with dark gray veins, and tinges of grayish-purple.

It is a marble of great beauty.

Breccia. This term is applied to brecciated marbles, or those which contain fragments of older rocks, held together by an intermediate material. It is sometimes termed Puddingstones, but this term should only apply

to those marbles in which the fragments are rounded instead of being angular.

The Italian Breccias are very beautiful.

Belgian marbles are few in number, and these are generally considered to be of a common and cheap class.

They have been most effectively worked by the Belgians, who, to their credit, have developed a marble trade which has made their country the principal European market for this class of colored marbles, both in the raw material and the worked-up. Their exportation of chimney-pieces alone must be of enormous magnitude.

St. Anne's marble is the best known and the most useful; it has a grayish-black ground with somewhat lighter shades, and flowered with white patches and veins. It is a sound marble of great utility, looks well, and takes a high polish.

Rouge Royal is a general term for several varieties of these marbles, all of which have fanciful names, such as Rouge Griotte, Rouge Fleurie, Rouge Rose, Rouge Byzantine, &c.; these, however, have much the same color and character throughout.

The best Rouge is considered to be of a dark brownish-red ground, with gray cloudings, and the veinings well marked, of a clear white.

Selected marble of this description has quite a handsome appearance.

It has come to be generally understood that to specify Rouge Griotte is to specify the best Rouge that can be obtained.

The defect in the Rouge consists of its being generally unsound, and containing clayish shakes, which require some amount of skill and ingenuity on the part of the workman in concealing with stopping.

A large quantity of the above two marbles (St. Anne's and Rouge) are worked up chiefly into chimney-pieces, table tops, fender curbs, &c., and imported into this country at a low price. This particular class of work is much cultivated in Belgium, where labor is cheap.

Blue Belge has a bluish-black ground, with fine white veins; it is a very useful marble, but is not well figured, as the veins run in straight lines, which become somewhat monotonous in appearance when polished; it is the most common of all the Belgian marbles.

Belgian Black is considered the finest black marble to be obtained in the world; no other country produces a marble that will compare with it in uniformity of color and closeness of texture. It takes a high polish. This marble is, however, difficult to work on account of its hard nature, and is therefore costly to produce.

Of French marbles there are a great number, most of which are very beautiful.

A few of those imported into this country are here given.

Griotte. This marble has a deep red ground, with numerous small spots or eyes scattered over the surface of pure pearly white, which gives it a beautiful appearance. It is difficult to work owing to its formation, which is much laminated, being similar to the leaves in a book, or, rather, the laminations in slate.

It will cut better one way with the chisel than the other, and sand and water are the chief agents in its manipulation.

Languedoc is a bright red marble, streaked with white and gray veins. It is a very handsome marble, the white portion in some cases being semi-transparent.

The result of the sharp contrast in color between the

red and white is very striking, and much enhances its appearance.

It is quarried at Alais (Gard), in the old province of Languedoc, France.

Rouge Jasper is a marble in which tints of red and yellow appear side by side, with white in sharp contrast, and in irregular patches.

Lamartine. These marbles are known as Brocatelle's, and are found in the neighborhood of Molinges. They are considered to be very handsome, their contrasts of color being most pleasing. Jaune Lamartine is of a fine yellow ground, and profusely veined with fine pencillings of red and brown; it is the pick of the marbles of Molinges. Jaune Fleuri is another variety of the same; it is of similar appearance, but of a much darker yellow, some specimens being of a rich reddish brown, and the veins in it more closely distributed than in Jaune Lamartine.

Brocatelle Violet is another of the series; this has been the longest known and worked. The ground is of a violet tint, and it is veined and figured with white and yellow. It much resembles in appearance Spanish Brocatelle, but cannot quite compare with it in beauty.

Campan. The Campan marbles are so called from the situation of the quarries in the Upper Pyrenees; they are exceedingly beautiful, and present great varieties of color.

Campan Vert is the best known; it is of two kinds, the clear and the dark. The former has very light shades of green, softly blended with the veins of darker green. The dark variety has a ground of dark green, with numerous flesh-colored and red spots, interspersed with thin white veins. Campan Rouge has a dull red ground,

with veins of darker red and bronze-green, mixed with flesh-colored and greenish-white spots. CAMPAN ISABELLE has a rose-colored ground, merging, in some places, into a dark red, with a few white spots and pale green veins.

BROCATELLE D'ESPAGNE (Brocatella) is quarried near Tortosa, Catalonia, Spain.

It has a dark red ground, covered with yellowish-gray and clear white spots, with some violet spots and veins; it is composed of crushed shells, and is properly speaking a lumachello. It is a very beautiful and choice marble, but somewhat out of date at the present time.

EMPEROR'S RED is a Portuguese marble, and quarried in the neighborhood of Lisbon; it is of a mottled yellowish-pink, some large patches of light red occurring occasionally, with veinings of dark red and light brown.

The demand for it, however, is as yet only limited.

CIPPOLLINO. This name is given to marbles having a whitish ground traversed with veins of green talc. There are a number of varieties, and to this class belongs the rediscovered Antique Cippollino marble of Saillon, Switzerland. It is largely used in this country, chiefly for wall linings and internal decoration, for which its colorings render it particularly adapted. A kind found at Pentelicus, in Greece, is called STATUARY CIPPOLLINO.

A fine Cippollino is quarried at Onofrio, in Corsica, and other varieties are found at Basle, in Switzerland.

NUMIDIAN. The marbles bearing this name are of great variety, and are obtained near the village of Kleber, about twenty miles northeast of Oran, in the western part of Algiers. These marbles comprise a creamy white Marmor Bianco; a flesh-tinted Rosa; a fine variety of Cippollino; various speciments of Giallo Antico; yellow

marbles of various tints, and brecciated marbles, including Breccia Sanguine, Breccia Coronato, and Breccia Grande, the last named of a deep red color, slightly brecciated, and resembling Rosso Antico.

These breccias are all of great beauty, sound, and even in texture, and take a high polish.

All these marbles are shipped at Oran, Algiers.

Onyx (Mexican), quarried at Pueblos, near Vera Cruz. This marble is a splendid material for the decorative arts: every color may be found in it—green in all its gradations; white and grays of all tints; red, pink, black, violet, yellow, and even blue, and some portions resemble jade. Its density surpasses all known marbles, and it is considered to be the connecting link between precious stones and marble, being as easily worked as any other marble.

As the polish is equal to that of the finest and most precious stones, such as agate, amethyst, jade and onyx, and will last for many years, so it is adaptable for external as well as internal decoration: this same polish is produced as easily as upon any other fine marble. It can be cut as thin as glass, and is nearly as transparent, and in Mexico it is used in some of the cathedrals and churches for windows, giving that "dim religious light" so much valued.

Onyx (Algerian). This marble is translucent; its colors are usually amber and white; it is used chiefly for ornaments, small panels, &c.

Onyx (Brazilian). This is a green marble, that is most exquisitely veined with red and yellow, and more than compares in beauty with that produced in Mexico.

Table of Diameters, Circumferences, and Areas of Circles.

Diam.	Circumference	Area	Diam.	Circumference	Area	Diam.	Circumference	Area
1/8	.3927	.01227	3 1/8	9.8175	7.6699	6 1/8	19.242	29.464
1/4	.7854	.04909	3 1/4	10.210	8.2957	6 1/4	19.635	30.679
3/8	1.1781	.1104	3 3/8	10.602	8.9462	6 3/8	20.027	31.919
1/2	1.5708	.1963	3 1/2	10.995	9.6211	6 1/2	20.420	33.183
5/8	1.9635	.3068	3 5/8	11.388	10.320	6 5/8	20.813	34.471
3/4	2.3562	.4417	3 3/4	11.781	11.044	6 3/4	21.205	35.784
7/8	2.7489	.6013	3 7/8	12.173	11.793	6 7/8	21.598	37.122
1	3.1416	.7854	4	12.566	12.566	7	21.991	38.484
1 1/8	3.5343	.9940	4 1/8	12.959	13.364	7 1/8	22.383	39.871
1 1/4	3.9270	1.2271	4 1/4	13.351	14.186	7 1/4	22.776	41.282
1 3/8	4.3197	1.4848	4 3/8	13.744	15.033	7 3/8	23.169	42.718
1 1/2	4.7124	1.7671	4 1/2	14.137	15.904	7 1/2	23.562	44.178
1 5/8	5.1051	2.0739	4 5/8	14.529	16.800	7 5/8	23.954	45.663
1 3/4	5.4978	2.4052	4 3/4	14.922	17.720	7 3/4	24.347	47.173
1 7/8	5.8905	2.7611	4 7/8	15.315	18.665	7 7/8	24.740	48.707
2	6.2832	3.1416	5	15.708	19.635	8	25.132	50.265
2 1/8	6.6759	3.5465	5 1/8	16.100	20.629	8 1/8	25.515	51.848
2 1/4	7.0686	3.9760	5 1/4	16.493	21.647	8 1/4	25.918	53.456
2 3/8	7.4613	4.4302	5 3/8	16.886	22.690	8 3/8	26.310	55.088
2 1/2	7.8540	4.9087	5 1/2	17.278	23.758	8 1/2	26.703	56.745
2 5/8	8.2467	5.4119	5 5/8	17.671	24.850	8 5/8	27.096	58.426
2 3/4	8.6394	5.9395	5 3/4	18.064	25.967	8 3/4	27.489	60.132
2 7/8	9.0321	6.4918	5 7/8	18.457	27.108	8 7/8	27.881	61.862
3	9.4248	7.0686	6	18.849	28.274	9	28.274	63.617

TABLE OF DIAMETERS, CIRCUMFERENCES, AND AREAS OF CIRCLES.—(Continued)

Diam.	Circumference	Area	Diam.	Circumference	Area	Diam.	Circumference	Area
9 1/8	28.667	65.396	12 1/8	38.091	115.466	15 1/8	47.516	179.672
9 1/4	29.059	67.200	12 1/4	38.484	117.859	15 1/4	47.909	182.654
9 3/8	29.452	69.029	12 3/8	38.877	120.276	15 3/8	48.302	185.661
9 1/2	29.845	70.882	12 1/2	39.270	122.718	15 1/2	48.694	188.692
9 5/8	30.237	72.759	12 5/8	39.662	125.184	15 5/8	49.087	191.748
9 3/4	30.630	74.662	12 3/4	40.055	127.676	15 3/4	49.480	194.828
9 7/8	31.023	76.588	12 7/8	40.448	130.192	15 7/8	49.872	197.933
10	31.416	78.540	13	40.840	132.732	16	50.265	201.062
10 1/8	31.808	80.515	13 1/8	41.233	135.297	16 1/8	50.658	204.216
10 1/4	32.201	82.516	13 1/4	41.626	137.886	16 1/4	51.051	207.394
10 3/8	32.594	84.540	13 3/8	42.018	140.500	16 3/8	51.443	210.597
10 1/2	32.986	86.590	13 1/2	42.411	143.139	16 1/2	51.836	213.825
10 5/8	33.379	88.664	13 5/8	42.804	145.802	16 5/8	52.229	217.077
10 3/4	33.772	90.762	13 3/4	43.197	148.489	16 3/4	52.621	220.353
10 7/8	34.164	92.885	13 7/8	43.589	151.201	16 7/8	53.014	223·654
11	34.557	95.033	14	43.982	153.938	17	53.407	226.980
11 1/8	34.950	97.205	14 1/8	44.375	156.699	17 1/8	53.799	230.330
11 1/4	35.343	99.402	14 1/4	44.767	159.485	17 1/4	54.192	233.705
11 3/8	35.735	101.623	14 3/8	45.160	162.295	17 3/8	54.585	237.104
11 1/2	36.128	103.869	14 1/2	45.553	165.130	17 1/2	54.978	240.528
11 5/8	36.521	106.139	14 5/8	45.945	167.989	17 5/8	55.370	243.977
11 3/4	36.913	108.434	14 3/4	46.338	170.873	17 3/4	55.763	247.450
11 7/8	37.306	110.753	14 7/8	46.731	173.782	17 7/8	56.156	250.947
12	37.699	113.097	15	47.124	176.715	18	56.548	254.469

TABLE OF DIAMETERS, CIRCUMFERENCES, AND AREAS OF CIRCLES.—(Continued)

Diam.	Circumference	Area	Diam.	Circumference	Area	Diam.	Circumference	Area
18⅛	56.941	258.016	21⅛	66.366	350.497	24¼	76.183	461.864
18¼	57.334	261.587	21¼	66.759	354.657	24½	76.969	471.436
18⅜	57.726	265.182	21⅜	67.151	358.841	24¾	77.754	481.106
18½	58.119	268.803	21½	67.544	363.051	25	78.540	490.875
18⅝	58.512	272.447	21⅝	67.937	367.284	25¼	79.325	500.741
18¾	58.905	276.117	21¾	68.329	371.543	25½	80.110	510.706
18⅞	59.297	279.811	21⅞	68.722	375.826	25¾	80.896	520.769
19	59.690	283.529	22	69.115	380.133	26	81.681	530.930
19⅛	60.083	287.272	22⅛	69.507	384.465	26¼	82.467	541.189
19¼	60.475	291.039	22¼	69.900	388.822	26½	83.252	551.547
19⅜	60.868	294.831	22⅜	70.293	393.203	26¾	84.037	562.002
19½	61.261	298.648	22½	70.686	397.608	27	84.823	572.556
19⅝	61.653	302.489	22⅝	71.078	402.038	27¼	85.608	582.208
19¾	62.046	306.355	22¾	71.471	406.493	27½	86.394	593.958
19⅞	62.439	310.245	22⅞	71.864	410.972	27¾	87.179	604.807
20	62.832	314.160	23	72.256	415.476	28	87.964	615.753
20⅛	63.224	318.099	23⅛	72.649	420.004	28¼	88.750	626.798
20¼	63.617	322.063	23¼	73.042	424.557	28½	89.535	637.941
20⅜	64.010	326.051	23⅜	73.434	429.135	28¾	90.321	649.182
20½	64.402	330.064	23½	73.827	433.731	29	91.106	660.521
20⅝	64.795	334.101	23⅝	74.220	438.363	29¼	91.891	671.958
20¾	65.188	338.163	23¾	74.613	443.014	29½	92.677	683.494
20⅞	65.580	342.250	23⅞	75.005	447.699	29¾	93.462	695.128
21	65.973	346.361	24	75.398	452.390	30	94.248	706.860

TABLE OF DIAMETERS, CIRCUMFERENCES, AND AREAS OF CIRCLES.—(Continued)

Diam.	Circumference	Area	Diam.	Circumference	Area	Diam.	Circumference	Area
30¼	95.033	718.690	36¼	113.883	1032.06	42¼	132.732	1401.98
30½	95.818	730.618	36½	114.668	1046.35	42½	133.518	1418.62
30¾	96.604	742.644	36¾	115.453	1060.73	42¾	134.303	1435.36
31	97.389	754.769	37	116.239	1075.21	43	135.088	1452.20
31¼	98.175	766.992	37¼	117.024	1089.79	43¼	135.874	1469.13
31½	98.968	779.313	37½	117.810	1104.46	43½	136.659	1486.17
31¾	99.745	791.732	37¾	118.595	1119.24	43¾	137.445	1503.30
32	100.531	804.249	38	119.380	1134.11	44	138.230	1520.53
32¼	101.316	816.865	38¼	120.166	1149.08	44¼	139.015	1537.86
32½	102.102	829.578	38½	120.951	1164.15	44½	139.801	1555.28
32¾	102.887	842.390	38¾	121.737	1179.32	44¾	140.586	1572.81
33	103.672	855.30	39	122.522	1194.59	45	141.372	1590.43
33¼	104.458	868.30	39¼	123.307	1209.95	45¼	142.157	1608.15
33½	105.243	881.41	39½	124.093	1225.42	45½	142.942	1625.97
33¾	106.029	894.61	39¾	124.878	1240.98	45¾	143.728	1643.89
34	106.814	907.92	40	125.664	1256.64	46	144.513	1661.90
34¼	107.599	921.32	40¼	126.449	1272.39	46¼	145.299	1680.01
34½	108.385	934.82	40½	127.234	1288.25	46½	146.084	1698.23
34¾	109.170	948.81	40¾	128.020	1304.50	46¾	146.869	1716.54
35	109.956	962.11	41	128.805	1320.25	47	147.655	1734.94
35¼	110.741	975.90	41¼	129.591	1336.40	47¼	148.440	1753.45
35½	111.526	989.80	41½	130.396	1352.65	47½	149.226	1772.05
35¾	112.312	1003.78	41¾	131.161	1369.00	47¾	150.011	1790.76
36	113.097	1017.87	42	131.947	1385.44	48	150.796	1809.56

TABLE OF DIAMETERS, CIRCUMFERENCES, AND AREAS OF CIRCLES.—(Continued)

Diam.	Circumference	Area	Diam.	Circumference	Area	Diam.	Circumference	Area
48¼	151.582	1828.46	54¼	170.431	2311.48	60¼	189.281	2851.05
48½	152.367	1847.45	54½	171.217	2332.83	60½	190.066	2874.76
48¾	153.153	1866.55	54¾	172.002	2354.28	60¾	190.852	2898.56
49	153.938	1885.74	55	172.788	2375.83	61	191.637	2922.47
49¼	154.723	1905.03	55¼	173.573	2397.48	61¼	192.423	2946.47
49½	155.509	1924.42	55½	174.358	2419.22	61½	193.208	2970.57
49¾	156.294	1943.91	55¾	175.144	2441.07	61¾	193.993	2994.77
50	157.080	1963.50	56	175.929	2463.01	62	194.779	3019.07
50¼	157.865	1983.18	56¼	176.715	2485.05	62¼	195.564	3043.47
50½	158.650	2002.96	56½	177.500	2507.19	62½	196.350	3067.96
50¾	159.436	2022.84	56¾	178.285	2529.42	62¾	197.135	3092.56
51	160.221	2042.82	57	179.071	2551.76	63	197.920	3117.25
51¼	161.007	2062.90	57¼	179.856	2574.19	63¼	198.706	3142.04
51½	161.792	2083.07	57½	180.642	2596.72	63½	199.491	3166.92
51¾	162.577	2103.35	57¾	181.427	2619.35	63¾	200.277	3191.91
52	163.363	2123.72	58	182.212	2642.08	64	201.062	3216.99
52¼	164.148	2144.19	58¼	182.998	2664.91	64¼	201.847	3242.17
52½	164.934	2164.75	58½	183.783	2687.83	64½	202.633	3267.46
52¾	165.719	2185.42	58¾	184.569	2710.85	64¾	203.418	3292.83
53	166.504	2206.18	59	185.354	2733.97	65	204.204	3318.31
53¼	167.290	2227.05	59¼	186.139	2757.19	65¼	204.989	3343.88
53½	168.075	2248.01	59½	186.925	2780.51	65½	205.774	3369.56
53¾	168.861	2269.06	59¾	187.710	2802.92	65¾	206.560	3395.33
54	169.646	2290.22	60	188.496	2827.44	66	207.345	3421.20

TABLE OF DIAMETERS, CIRCUMFERENCES, AND AREAS OF CIRCLES.—(Continued)

Diam.	Circumference	Area	Diam.	Circumference	Area	Diam.	Circumference	Area
66¼	208.131	3447.16	72¼	226.980	4099.83	78¼	245.830	4809.05
66½	208.916	3473.23	72½	227.766	4128.25	78½	246.615	4839.83
66¾	209.701	3499.39	72¾	228.551	4156.77	78¾	247.401	4870.70
67	210.487	3525.66	73	229.336	4185.39	79	248.186	4901.68
67¼	211.272	3552.01	73¼	230.122	4214.11	79¼	248.971	4932.75
67½	212.058	3578.47	73½	230.907	4242.92	79½	249.757	4963.92
67¾	212.843	3605.03	73¾	231.693	4271.83	79¾	250.542	4995.19
68	213.628	3631.68	74	232.478	4300.85	80	251.328	5026.56
68¼	214.414	3658.44	74¼	233.263	4329.95	80¼	252.113	5058.00
68½	215.199	3685.29	74½	234.049	4359.16	80½	252.898	5089.58
68¾	215.985	3712.24	74¾	234.834	4388.47	80¾	253.683	5121.22
69	216.770	3739.28	75	235.620	4417.87	81	254.469	5153.00
69¼	217.555	3766.43	75¼	236.405	4447.37	81¼	255.254	5184.84
69½	218.341	3793.67	75½	237.190	4476.97	81½	256.040	5216.82
69¾	219.126	3821.02	75¾	237.976	4506.67	81¾	256.825	5248.84
70	219.912	3848.46	76	238.761	4536.47	82	257.611	5281.02
70¼	220.697	3875.99	76¼	239.547	4566.36	82¼	258.396	5313.28
70½	221.482	3903.63	76½	240.332	4596.35	82½	259.182	5345.62
70¾	222.268	3931.36	76¾	241.117	4626.44	82¾	259.967	5378.04
71	223.053	3959.20	77	241.903	4656.63	83	260.752	5410.62
71¼	223.839	3987.13	77¼	242.688	4686.92	83¼	261.537	5443.24
71½	224.624	4015.16	77½	243.474	4717.30	83½	262.323	5476.00
71¾	225.409	4043.28	77¾	244.259	4747.79	83¾	263.108	5508.84
72	226.195	4071.51	78	245.044	4778.37	84	263.894	5541.78

TABLE OF DIAMETERS, CIRCUMFERENCES, AND AREAS OF CIRCLES.—(Continued)

Diam.	Circumference	Area	Diam.	Circumference	Area	Diam.	Circumference	Area
84¼	264.679	5574.80	88¼	277.245	6116.72	92¼	289.812	6683.80
84½	265.465	5607.95	88½	278.031	6151.44	92½	290.598	6720.07
84¾	266.250	5641.16	88¾	278.816	6186.20	92¾	291.386	6756.40
85	267.036	5674.51	89	279.602	6221.15	93	292.168	6792.92
85¼	267.821	5707.92	89¼	280.387	6256.12	93¼	292.953	6829.48
85½	268.606	5741.47	89½	281.173	6291.25	93½	293.739	6866.16
85¾	269.392	5775.09	89¾	281.958	6326.44	93¾	294.524	6882.92
86	270.177	5808.81	90	282.744	6361.74	94	295.310	6939.79
86¼	270.962	5842.60	90¼	283.529	6399.12	94¼	296.095	6976.72
86½	271.748	5876.55	90½	284.314	6432.62	94½	296.881	7013.81
86¾	272.533	5910.52	90¾	285.099	6468.16	94¾	297.666	7050.92
87	273.319	5944.69	91	285.885	6503.89	95	298.452	7088.23
87¼	274.104	5978.88	91¼	286.670	6539.68	95¼	299.237	7125.56
87½	274.890	6013.21	91½	287.456	6573.56	95½	300.022	7163.04
87¾	275.675	6047.60	91¾	288.242	6611.52	95¾	300.807	7200.56
88	276.460	6082.13	92	289.027	6647.62	96	301.593	7238.24

NOTE.—THE CIRCUMFERENCES OF LARGER CIRCLES (up to 200 ft.) than those above given may be found by taking one half of the diameter—finding the circumference of such half by the above table, and then multiplying by 2.

THE AREA OF CIRCLES OF LARGER DIAMETERS (up to 200 ft.) than those above given may be found by taking one half of the diameter of the proposed circle—finding the area of same by above table, and multiplying this area by 4. Circles being to each other as the squares of their diameters.

GLOSSARY OF TERMS.

ABACUS. The tablet or the upper member of the capital of a column; varying in the several orders and styles.

ABUTMENT. The solid part of a pier which receives the thrust or lateral pressure of the arch, and from which the arch immediately springs.

ALABASTER. A white translucent species of gypsum or sulphate of lime, composed of crystalline grains in a compact mass. It is capable of being worked to a high degree of finish, and taking a fine polish.

It is much used for interior decorations, monuments, &c.

ANNULAR VAULT. A vault springing from two walls, each circular on plan.

ANNULET. A small fillet encircling a column, used either alone or in connection with other mouldings.

ARC. In geometry, a portion of the circumference of a circle or other curve line.

ARCADE. A covered passage composed generally of a range of arches, supported either on columns or piers, and detached from or attached to the wall.

ARCH. A concave or hollow structure supported by its own curve.

A number of wedge-shaped stones disposed in the line of some curve, and supporting each other by their mutual pressure.

The arch itself is composed of voussoirs, or arch stones, the uppermost of which is called the keystone.

ARCHITRAVE. The lower of the three principal members of the entablature of an order, being the chief beam resting immediately on the columns.

A collection of mouldings round a door, window, or other aperture. See also Entablature.

ARCHIVOLT. The band of mouldings round the arch stones of an arch, which terminates horizontally upon the impost.

ARRIS. The line or edge on which two surfaces forming an exterior angle meet each other, either plane or curved.

ASHLAR. A term for hewn or squared stone, as distinguished from unwrought material; it is generally used for facings, and set in horizontal courses, and bears various names according to the manner in which it is worked, such as Plain Ashlar, Tooled Ashlar, Rustic Ashlar, &c.

ASTRAGAL. A small moulding of a semicircular profile. The name is generally applied to the necking separating the capital from the column. See also Moulding.

AXIS OF A CYLINDER. A right line passing through the solid, from the centre of one of the circular ends to the centre of the other, and the line on which such a body may be conceived to revolve.

AXIS OF A DOME. A right line perpendicular to the horizon, passing through the centre of its base.

BANKER. A block of stone forming a bench on which the stone is worked.

BASE. In geometry, the lower part of a figure or body.

The base of a solid is the surface on which it rests.

In masonry, the lower moulded part, between the shaft and the pedestal.

BATTER. A wall that inclines inward from a vertical or plumb line, so that the upper part of the surface falls within the base.

BED. The horizontal surface on which a stone lies. The beds of a stone are the surfaces where the stones meet; the upper surface is called the top bed, and the under surface the bottom bed. See also Natural Bed.

BILLET MOULDING. A Norman moulding used in arches, strings, &c.; it consists of small short lengths of beads or bars, cut in hollow mouldings, with spaces between equal to the length of the billet. See also Moulding.

BLOCKING-COURSE. A course of stones placed on the top of a cornice, forming the summit of the wall.

BOASTING. Cutting the stone roughly to form of intended carving.

BOND. The disposition or lapping of the stones so that vertical joints may not fall over one another, but fall directly over the middle of the stone below, in order to form an inseparable mass of building

BOND-STONE. Stones whose longest horizontal direction is placed in the thickness of the work, for the purpose of binding the wall together.

BONING. The art of testing a plane surface by the guidance of the eye and the aid of two straight-edges, by which it is seen whether the work is out of winding, or whether the surface be plane or twisted.

BOSS. A sculptured or carved projection to conceal the intersection of the moulded ribs in a vault, or at the stop end of a string course or label.

BREAKING JOINT. The placing of a stone over the course below, in such a position that the joint above shall not fall vertically directly over the joint below it.

BUTTRESS. A pier of masonry projecting from a wall to support and strengthen it. Buttresses are employed in Gothic buildings to resist the thrust of the vaulting and roof, and also to stiffen walls and towers of great height.

CAMBER. The slightly hollowed soffit given to a lintel or flat arch to correct the apparent sinking down in the centre.

CANOPY. An ornamental projection over windows, doors, niches, &c.

CANT. An external splay angle cut off a square.

CANTILEVER. A large projecting bracket to support cornices, balconies, eaves, &c.

CAPITAL. The head or uppermost member of a column pier, or pilaster, in any part of a building, but generally applied to that of a column or pilaster of the several orders.

CHAMFER. The arris of a solid cut to a bevelled plane.

CHEVRON. A zigzag or V-shaped ornament used in mouldings, chiefly to arches in Norman work.

CHISELLED WORK. The surface of a stone formed by the chisel.

CHORD. In geometry, a straight line drawn from any point of an arc to any other point of that arc.

CIRCLE. A plane figure, of which its boundary is everywhere at an equal distance from a point within its surface, called its centre.

Its perimeter encloses the largest area of any figure.

CIRCULAR WORK. A term applied to any work with cylindric faces.

CIRCUMFERENCE. The curve line which bounds the area of a circle.

Circumscribe. To draw a line round a figure so as to enclose it.

Closer. The last stone fixed in a horizontal course which is usually of less dimensions than the others.

Coffer. A sunk panel in vaults, domes, and arches. The name is also applied to any sunk panel in a ceiling or soffit.

Column. A cylindrical or polygonal pier, which supports a superincumbent weight in a vertical direction; it is generally composed of a base, shaft, and capital. See also Pilaster.

Concave. A hollow line or surface, as the soffit of an arch, vault, or the inner surface of a sphere.

Concentric. Having the same centre but different radii.

Conic Sections. The figures formed by the intersections of a plane with a cone, which do not include the triangle or the circle. These three sections are the ellipse, parabola, and hyperbola.

Contour. The outline of a figure or body; the line that bounds.

Convex. A rising or swelling on the exterior surface into a round or spherical form, as the outside of a sphere, the extrados of an arch, &c.

Coping. The highest and top covering course in a wall.

Corbel. A small bracket projecting from the wall to support some superincumbent weight.

Cornice. A horizontal projection, moulded, decorated, or otherwise, which crowns or terminates a wall, building, pedestal, or other piece of work.

Course. A row of stones of the same height generally placed on a level bed. The stones round the face and intrados of an arch, are also called a course of stones.

Coursing Joint. The joint between two courses of stone.

Crown of an Arch. The highest or central part of an arch or any arched surface.

Cupola. A concave ceiling or roof, hemispherical or nearly so. A small dome.

Curtail Step. The first or bottom step of a stairs, generally of a curved form on plan, and a curved quoin end.

Curve Line. A concave or convex line.

Cusp. A triangular projection from an inner curve of a tracery arch or window.

Cylinder. A circular body of uniform diameter, whose ends or base form equal parallel circles, and whose curved surface is everywhere at an equal distance from its axis.

The cone, sphere, and cylinder have a relative value to each other, namely, that the cone is one-third the cylinder having the same base and height; and the inscribed sphere two-thirds of the cylinder, or the cone, sphere, and cylinder are to each other as the numbers 1, 2, 3.

Cylindrical Work. Any form of work which partakes of the shape of a cylinder.

Dentals. The small square blocks or teeth cut in the bed mould or cornices, pediments, &c.

Development. The unrolling or laying out of a surface upon a plane, so that every point of the surface may coincide with the plane.

Diagonal. A straight line drawn through a plane figure, joining two opposite angles.

Diameter. A straight line passing through the centre of a curvilinear figure, and dividing the figure sym-

metrically into two equal parts, terminating in the circumference on each side, as that of a circle or ellipse.

Diminution of a Column. The gradual contraction of the diameter of a column, so that the upper diameter is less than the lower.

Dome. The spherical or convex roof raised over a circular or polygonal building. There is great variety in the forms of domes, both in plan and section. See also Cupola.

Draft. A margin on the surface of a stone dressed to the width of the chisel or bolster, for the purpose of directing its reduction to the required surface.

Dressed. A term which expresses the preparation a stone has undergone, before fixing in its position in the building.

Edge. The meeting in an external angle of two planes or surfaces of a solid.

Elevation. A geometrical projection drawn on a plane perpendicular to the horizon.

Ellipse or Ellipsis. One of the conic sections, produced by cutting a cone by a plane passing obliquely through the opposite sides. It may be divided into two equal and similar parts, by a diameter drawn in any direction.

Entablature. The superstructure which lies horizontally upon architectural columns. It consists of three portions: the architrave, which rests immediately upon the columns, the frieze or central portion, and the cornice.

Entasis. A refined and almost imperceptible swelling of the shaft of a column.

Equiangular. Having equal angles.

Equidistant. At equal distances.

Equilateral. Having equal sides.

Extrados. The exterior or convex curve of an arch.

Face-mould. A pattern or templet defining the form to which a stone is to be worked. It is usually made of sheet zinc.

Fillet. A small moulding of square section. Also the space between two flutings in a column or pilaster.

Finial. The top or finishing terminal to a gable or pinnacle.

Flush. The bedding of masonry blocks in mortar or cement, completely filling in all interstices in the beds and joints.

The term is also used to signify the breaking off or chipping any portion of a dressed stone.

Flute. A perpendicular hollow or channel; used to decorate the shafts of columns or pilasters.

Flyers. Steps in a flight of stairs, whose edges are parallel to each other.

Foci. The two points in the major axis of an ellipse to which a string may be fixed so as to describe the curve.

Free-stone. A stone which can be freely worked in any direction.

Gargoyle. A projecting waterspout usually carved into a grotesque head.

Gauge. The measure to which any dimension is confined.

Geometry. The science which explains, and the art which shows, the construction of lines, angles, plane figures, and solids.

Grit-stone. A coarse or fine-grained sandstone of various degrees of hardness. It is composed of small grains of sand united by a cementing material of an argillaceous, calcareous, or siliceous nature.

GROIN. The curved line formed by the intersection of two arches or vaults crossing each other at any angle.

GROINED VAULT. One formed by three or more curved surfaces, so that every two may form a groin, all the groins terminating at one extremity in a common point.

GROUND LINE. The straight line upon which the vertical plane of projection is placed.

GROUT. A thin semi-liquid mortar composed of cement and sand or lime and sand, and run into the joints and beds of stonework, filling all interstices.

GYPSUM. Crystals of native sulphate of lime. Being subjected to a moderate heat, to expel the water of crystallization, it forms plaster of Paris, and, coming in contact with water, immediately assumes a solid form. Of the numerous species, alabaster is, perhaps, the most abundant.

HEADER. Stones extending through the thickness of a wall, as bond-stones.

HEADING. The vertical side of a stone perpendicular to the face.

HEADING JOINT. The thin stratum of mortar between the vertical surfaces of two adjacent stones.

HELIX. A spiral winding round the surface of a cylinder.

HEMISPHERE. One half of a globe or sphere, when divided through its centre by a plane.

HYPOTHENUSE. The longest side of a right-angled triangle. The side opposite to the right angle.

IMPOST. The capital of a pier or pilaster from which an arch springs.

Its form varies in the different orders.

INCLINATION. The angle contained between a line and a plane, or between two planes.

INTERSECTION. The point on which two lines meet and cut each other.

The line in which two surfaces cut or meet each other.

INTRADOS. The inner curve of an arch.

JAMBS. The vertical sides of a window or door opening, which connect the two sides of a wall.

JOGGLE. An indentation made in one stone, called the she joggle, to receive the projection on another termed the he joggle.

JOINT. The surface of contact between two adjacent blocks of stone.

JUMPER. A long steel chisel used for drilling holes.

KEY COURSE. The horizontal range of stones in the summit of a vault, in which the course is placed.

KEYSTONE. The highest central stone in the crown of an arch. See Arch.

LABEL. The drip or hood moulding over the apertures in Gothic windows and doors.

LANCET ARCH. Narrow window heads shaped like the point of a lancet, and characteristic of the Early English Gothic (13th century).

LANDING. The terminating floor of a flight of stairs, either above or below it; or the level part of a staircase connecting one flight with another.

LEVEL. A line or surface horizontal or parallel to the horizon; or a straight line perpendicular to a plumb line.

LINE OF BATTER. The line of section made by a plane and the surface of a battering wall, the plane being perpendicular both to the surface of the wall and to the horizon.

Lintel. A stone which extends over the aperture of a door or window, and carries the superincumbent weight by means of its strength or resistance.

Marble. A term limited by mineralogists and geologists to the several varieties of carbonate of lime, having more or less of a granular and crystalline texture. It is susceptible of a very fine polish, and the varieties of it are extremely numerous.

Marble, Polishing of. Marbles are of such varied nature that one method of polishing cannot be adopted for all, although the following method will suffice for Statuary, Vein, Sicilian, St. Anne's, and most of the ordinary colored marbles in general use.

The wrought surface is rubbed with fine sharp sand and water, until all the marks of the chisel or saw are removed, and an even face is produced; it is then "grounded," that is, rubbed with grit stones of varying degrees of fineness, commencing with the coarse or "first grit," next the "second grit," which is a little finer, and then finishing with "snake" or "Water of Ayr" stone. Particular care must be taken that in each process of "gritting" the marks or scratches of its predecessor are removed, so that when the surface is "snaked" no scratches whatever are visible, but left quite smooth, for upon the careful "gritting" depends the success of the ultimate polish.

The polishing is lastly effected by rubbing with a pad of felt sprinkled with putty powder (calcined tin) moistened with water, until the gloss or natural polish is obtained.

The polishing of marble adds greatly to its beauty, inasmuch as its delicate figuring, and gradations of rich coloring, are brought out and heightened by the

process, which thus makes it so valuable as a decorative material.

MASONRY. The art of shaping, arranging, and uniting stones, in the construction of walls and other parts of buildings.

METOPES. The square spaces between triglyphs in the frieze of the Doric order; sometimes applied to the sculptures fitted into these spaces.

MODILLION. A projecting enriched bracket in the soffit of the top bed of a cornice.

MONOLITH. Consisting of one stone.

MORTISE. A sinking in a stone to receive a corresponding projection.

MOULD. A templet or pattern defining the form of the stone which is to be worked. It is usually made of sheet zinc.

MOULDING. The outline or contour given to an angle whether a projection or a cavity.

Mouldings may be generally resolved into three elementary forms—hollow, round, and square—and it is upon the choice, arrangement, and proportion of these forms that beauty or ugliness depends. Of the two main principles in connection with mouldings, namely, projection and recession, the former is generally adopted in Classical and Renaissance architecture, and the latter in Gothic. The most perfect profiles are such as are composed of few mouldings, varied and alternating both in form and size, fitly applied with regard to their uses, and so disposed that the straight and curved members succeed each other alternately. In every profile there should be a prominent member, to which all the others should be subservient, and appear

to support and fortify, or to shelter it from injury by the weather.

Mullion. The upright post or bars of stone which subdivide a window into two or more lights. See also Transom.

Mural. Belonging or attached to a wall.

Mutule. A projecting ornament in a Doric cornice, somewhat resembling the end of a timber beam; it occupies the place of a modillion in the other orders.

Natural Bed of a Stone. The direction in which the natural strata lie when in the quarry.

The line of the planes of cleavage.

Newel. The vertical column or pillar about which, in a winding stair, the steps turn, and receive support from the bottom to the top.

The newel step in an open stair is the bottom one; it is generally curvilinear on plan.

Niche. A semicircular or hollow recess generally within the thickness of a wall, for a statue, vase, or other ornament.

Normal. A right line perpendicular to the tangent of a curve.

Ordinate. A line drawn from any part of the circumference of an ellipse or other conic section, perpendicular to, and across the axis to the other side.

Parabola. One of the three conic sections.

An open curve of which both of its branches may be extended infinitely without ever meeting.

It is produced by cutting a cone by a plane parallel to one of its sides, and so named because its axis is parallel to the side of the cone.

Parallel. Lines, surfaces, &c., that are in every part

equidistant from each other, and extended in the same direction.

PEDIMENT. A triangular, or gabled termination to a building, sometimes also placed over doors, windows, porticoes, &c.

PERPENDICULAR. A line at right angles to a given line.

PIER, PILLAR. See Column.

PILASTER. A square column usually attached to a wall from which it projects. In most cases it corresponds to the columns of its order, having a similar capital, shaft, and base.

PLANE. A perfectly flat or level surface, coinciding in every direction with a straight line.

PLINTH. The base of a wall, column, &c.

PROFILE. The contour outline of mouldings taken at right angles to their length.

PROJECTION. The art of representing any object on a plane by means of straight lines, drawn from all visible parts of those objects to intersect the plane of projection.

QUADRANT. The fourth part of a circle; an arc of ninety degrees.

QUOINS. The courses of stone to any external angle of a building.

RADIATING JOINTS. Those joints which tend to a center.

RADIUS. A right line drawn from the center to the circumference of a circle. The semidiameter of a circle or sphere.

RAKING MOULDINGS. Mouldings which run in an inclined position.

RIB. A narrow arch-formed bar projecting beyond the surface of a vault, to mark its intersection and to add strength.

Rustic Quoins. The coursed stones to the external angles of a building, projecting beyond the face of the wall.

Sandstone. A stone composed of grains of sand, united with other mineral substances, cemented together by a material of an argillaceous, calcareous, or siliceous nature.

Scribe. To scratch in on the stone, with a sharp pointed tool, the profile of a mould, templet, &c.

Section. The figure formed by cutting a solid by a plane.

Segment of a Circle. A portion of a circle contained by an arc and its chord.

Setting. A term used to denote the fixing of dressed stones in their proper position in the walls of buildings.

Shaft. The cylindrical part of a column between the base and the capital.

Soffit or Sofite. The under surface of any part of a ceiling, architrave, arch, vault, stairs, &c.

Soffit Joints. Those joints which appear on the under surface.

Span. The distance or dimension across the opening of an arch, window, or aperture.

Spandrel. A triangular-shaped piece. The irregular triangular space between the curve of an arch and the rectangle inclosing it; or the space between the outer mouldings of two contiguous arches and a horizontal line above them.

Spiral. The helix or screw.

A curve consisting of one or more revolutions round a fixed point and gradually receding from it.

Spire. A steeple diminishing as it ascends, generally octagonal on plan.

SPLAY. A slope making with the face of a wall an angle less than a right angle.

STAIR. One step of a series by means of which a person ascends or descends to a different landing.

A series of steps for passing from one part of a building to another.

STAIRCASE. A flight of stairs with their supporting framework, casing, balusters, &c., which enable persons to ascend or descend from one floor to another.

STILTED ARCH. An arch in which the springing line or curve does not commence for some distance above the level of the impost.

STONE CUTTING. The art of hewing or dressing stones to their intended form.

STRAIGHT-EDGE. A rule whose edge coincides with a straight line.

STRETCHER. A stone laid with its longer face in the surface of the wall.

TANGENT. A straight line which touches a curve without cutting it.

TANGENT PLANE. A plane which touches a curved surface without being able to cut it.

TEMPLET. A mould giving the contour to which stones are to be wrought.

TRANSOM. A horizontal bar across a window of two or more lights. See also Mullion.

TRIANGLE. A plane figure consisting of three sides.

TRIHEDRAL. A solid angle consisting of three plane angles.

TRISECTION. The division into three equal parts.

TYMPANUM. The triangular face of a pediment included between the horizontal and raking mouldings.

Vault. An arched roof or ceiling over an apartment, so constructed that the stones of which it is composed sustain and keep each other in their places.

Vertical Plane. A plane perpendicular to the horizon.

Volute. A spiral scroll as in the Ionic capital.

Voussoir. A wedge shaped stone forming one of the blocks of an arch.

Weathering. A sloping surface of stone employed to cover the set-off of a wall or buttress, and protect it from the effects of the weather.

Welch Groin. A groin formed by the intersection of two cylindrical vaults, one being of greater height than the other.

Winder. One in a flight of steps which are curved on plan, having each tread broader at one end than the other.

Wreathed Column. Twisted in the form of a screw or spiral.

APPENDIX

In order to make this book as useful as possible I have thought it proper to add this Appendix to it, which, in my opinion, offers the best and most simple solutions to the problems discussed in this department. It is taken from the works of Wm. R. Purchase, one of the best known authorities on Cut Stone Masonry. The subjects dealt with are of the most difficult kind known to the art of masonry, but here they are reduced to the simplest manner possible, and the rules are made so plain that any ordinary workman should be able to thoroughly understand them.

ARCHES

CIRCULAR ON PLAN, OR ARCHES OF DOUBLE CURVATURE

To describe the construction of a Semi-circular Arch in a Cylindrical Wall, the development of which on convex or outside face is a semi-circle, and on concave or inside face is a semi-ellipse, the soffit radiating to a center at springing, and the crown of the arch level or at right angles to the vertical face of the wall.

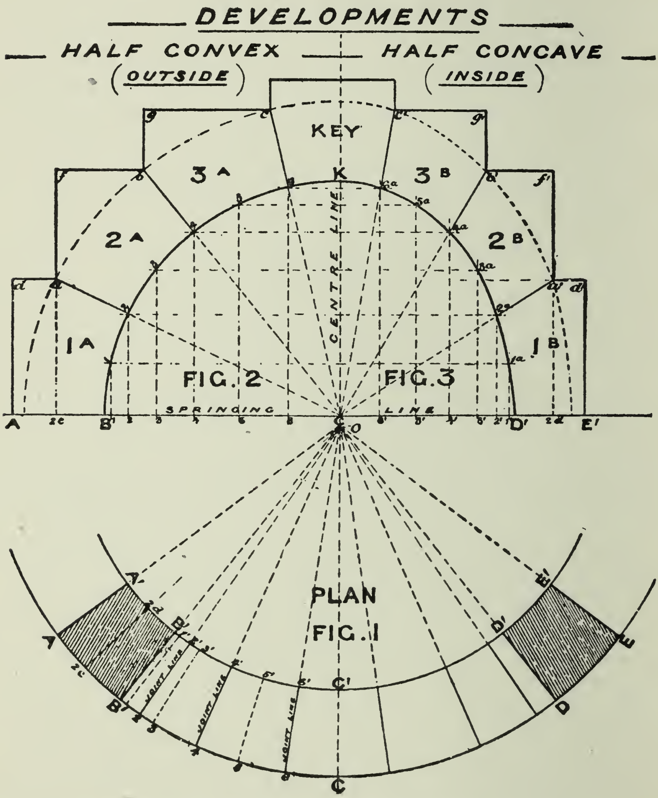
Fig. 1.—Shows plan of the arch, B C D being the opening, the arch radiating to O, the center of the cylinder.

To set up the Elevation on the Development for the Face Moulds.

Fig. 2.—Develop the segment A B C of convex face (Fig. 1), setting out the length on springing line as A B C from C as the center; erect a perpendicular as center line, and describe with C B as radius half of the semi-circle. Set off the joints radiating to the center C corresponding to the number of arch joints required, which in this example is seven. The square bonding *d a*, *f b*, *g c* of vertical and horizontal joints may be of varied sizes. The radiating joints (here shown) are made equal in length from the soffit, and for this purpose from the center C describe a quadrant, cutting the joints at *a b c*.

To find the Development of Concave Face.

FIG. 3.—Divide the quadrant B K (Fig. 2) into any number of equal parts—in this example seven—and draw the ordinates **1**, 2, 3, 4, 5, 6, projecting the same on to the springing line, and transfer these to the segment line B C on plan (Fig. 1) as **1, 2,**



3, 4, 5, 6, and from these points draw radiating lines from the center O, cutting the segment B′ C′ at 1′, 2′, 3′, 4′, 5′, 6′; draw the developed length of B′ C′ on springing line (which is also equal to C′ D′ and is half of the inside face) from C to D′; transfer

1′, 2′, 3′, 4′, 5′, 6′ from Fig. 1, and draw the ordinates of equal height to those of Fig. 2, cutting Fig. 3 at 1^a, 2^a, 3^a, 4^a, etc., through the points 1^a, 2^a, 3^a, 4^a, etc.; draw the half of semi-ellipse, which gives the curve of the arris to the soffit.

The length of the joints in Fig. 3 is determined in the same manner as in Fig. 2—namely, by means of ordinates. One joint is here given as an example:

From A No. 2 A (Fig. 2) drop a perpendicular cutting the springing line at 2 C; and from 2 C to 2 transfer to 2 C and 2 on the segment line of plan (Fig. 1), and draw radiating lines from 2 C to the center O, cutting the segment A′ C′ at 2 *d;* transfer the distance from 2 *d* to 2′ on to the springing line (Fig. 3). Set up ordinate and make equal in height to *a* on Fig. 2, and from 2 A to A′ (Fig. 3) draw joint line, which also radiates from the center C.

The moulds required for working each arch block are a bed mould and two face moulds (one to the convex and one to the concave face); these are already set out on plan and in developed elevations, but now require separating.

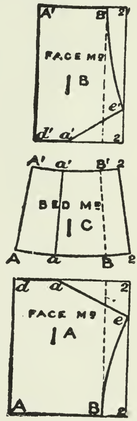


Fig. 4.

As an example, No. 1 A (Fig. 2) is the springer. For the bed mould take A B 2 and A′ B′ 2′ from plan (Fig. 1), and transfer to 1 C (Fig. 4).

The dotted line B B′ shows the line of the soffit on the bottom bed, the line *a a*′ the line of the arch joint on the top bed, A A′ the line of radiating vertical joint, and 2 2′ the line of arris of the arch joint. This gives the plan of a segment of a hollow cylinder to the extreme size of the stone.

No. 1 A (Fig. 4) is the face mould for convex face, No. 1 B (Fig. 4) is the face mould for concave face, and both of these are transferred from 1 A and 1 B (Figs. 2 and 3), with the addition of the square line 2 2 and 2′ 2′.

The stone for the arch block should be large enough to work the bed mould square through; if there is a "wanty" corner in the rough block, this may be arranged for in the corner where the stone has to be cut away for the soffit or the top joint.

Work the two beds bottom and top parallel to each other and of the height of the face mould, scribe in the bed mould No. 1 C on both beds (to be correct this should be boned in),

the vertical joint A d being at right angles to the bed. Next work the convex and concave faces through, and also the radiating joint A A′, the block at this stage being a portion of a hollow cylinder similar to sketch (Fig. 7).

Now scribe in the face moulds 1 A on the convex and 1 B on the concave faces (Fig. 4); next work the arch joint a e through (this will have a slight twist); and lastly, for the soffit cut in a draft B e on convex and B′ e' on concave faces, and work the surface through, thus completing the springer.

It may be observed that the soffit is a winding or warped surface, and it will be worked similar to the soffit of winder step, as previously described.

To work the Second Arch Stone, No. 2 *A* (*Fig.* 2).

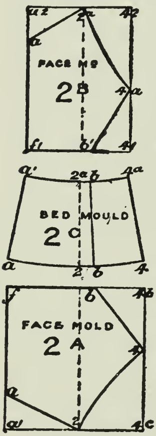


Fig. 5.

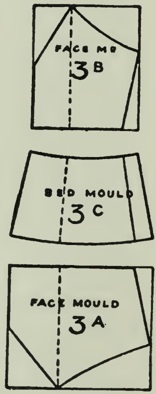


Fig. 6.

For the bed mould 2 C (Fig. 5), project the extreme points a and 4, No. 2 A (Fig. 2) on to springing line; transfer these to the segment line A C on the plan (Fig. 1). This gives from 2 C to 4 and 2 d to 4′, which encloses the bed mould; a a' is the vertical joint and arris of the arch joint a 2, the dotted line 2^a is the horizontal line of the joint on soffit at bottom, and the line b b' is the arris at the top of arch joint, 4 4 a is the bottom arris of the top joint to soffit.

No. 2 A (Fig. 5) is the face mould for the convex face, and No. 2 B (Fig. 5) is the face mould for the concave face; both of these are transferred from 2 A and 2 B (Figs. 2 and 3), with the addition of the square line 4 b, 4 C, and 4 1, 4 2.

Work the top bed first f b, 4 b, and take the bottom bed a 2, 4 C parallel to the top and of the height of the face mould (this is a surface of operation, all being cut away except arris 2 2 a, which must be kept true across the bed). Scribe the bed mould No. 2 C (Fig. 5) on both beds. Now work the two faces convex and concave through, and the radiating joint a a' square with

the top bed, bringing it again into the shape of a portion of hollow cylinder, as in sketch (Fig. 7).

Scribe the face mould 2 A on the convex and 2 B (Fig. 5) on concave faces. Work the arch joints *a* 2 and *b* 4, and for the soffit cut in the draft 2 4 on the convex and 2 *a*, 4 *a* on concave faces, and work through as previously described.

The other arch stone 3 A and keystone are worked in a similar manner, the general principles of working being the same.

Note.—The radiating joint lines on the developments (Figs. 2 and 3), to be geometrically correct, should not be straight, being slightly curved. This is apparent on cutting a cylinder by a right line obliquely, the development of which is a compound curve; but in this case the curve is so slight as to be scarcely perceptible, and need not in the present and the following example be taken notice of.

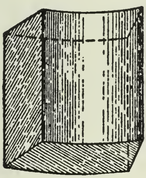


Fig. 7.

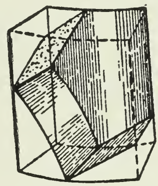


Fig. 8.

To construct a Semi-circular Arch in a Cylindrical Wall, whose line of soffit on the plan is parallel to the axis, the axes of the two cylinders intersecting each other at right angles.

Fig. 9.—Shows the plan of the arch, B C D being the opening.

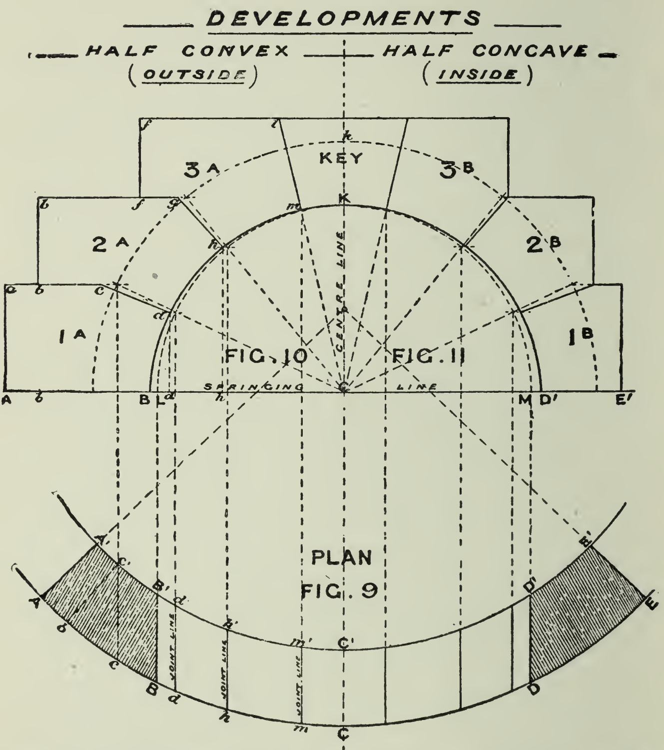
Figs. 10 and 11 are the developed elevations.

In order to prevent confusion with Figs. 9, 10, and 11, and to make matters easier of explanation, three diagrams are here shown, containing Fig. 15, Figs. 16, 17, and Figs. 18, 19, these being slightly exaggerated to show more clearly the working.

Let Fig. 15 be the plan of segment of cylinder, with the semi-cylinder penetrating the same at right angles to the axis at *a e*, *b d*.

Let Fig. 16 be the square section of the quadrant of cylinder, and divide this into any unequal number of equal parts corresponding to the number of arch stones required in Figs. 10 and 11, which in this example is seven, as 1, 2, 3, 4, 5, 6, 7, and pro-

ARCHES *CIRCULAR ON PLAN*



ject on to the segment line *a c b* on plan (Fig. 15), as C 6, 5, 4, 3, 2, 1; transfer this to the springing line *a b*, 1, 2, 3, 4, 5, 6, 7 (Fig. 17), which is now the developed line; erect ordinates, and make them equal in height to the ordinates of the square section, as 1′, 2′, 3′, 4′, etc.; draw line through the intersecting points 1′, 2′, 3′, 4′, etc., giving the curve required on the development at the point of penetration for the outside or convex face of cylinder.

For the development of the inside or concave face, let Fig. 18 be the square section, divided into seven equal parts, projecting the ordinates as before. Transfer from Fig. 15 1^a, 2^a, 3^a, 4^a, 5^a, 6^a, 7^a to the springing line (Fig. 19), erect ordinates and make them equal in height to those of square section at 1, 2, 3, 4, etc., and through the intersecting points 1^a, 2^a, 3^a, 4^a, etc., draw the line giving curve required at the point of penetration for the inside or concave face of cylinder.

For the joints draw radiating lines at 2, 4, 6 (Figs. 16 and 18), and to make them of equal length draw a quadrant line with radius of the square section as *f g h*, project *f g h* on to plan (Fig. 15) as *f g h*, and transfer to the springing line (Figs. 17 and

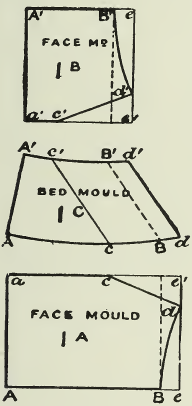


Fig. 12.

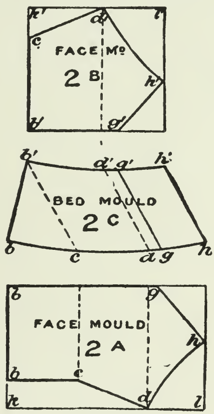


Fig. 13.

19); erect ordinates at *f g h*, making equal in height to those of the square section. Next draw the joint lines $h\,2'$, $g\,4'$, $f\,c'$ on Fig. 17, and $h\,2^a$, $g\,4^a$, and $f\,c'$ (Fig. 19); the developed length of joint is thus obtained.

To set up the Elevation on the Developments for the Face Moulds.

Figs 10 and 11.—Let A E′ be the springing line, C K the center line, and L K M dotted line the square section of the cylinder whose center is C. For the development B K D proceed as previously described, and divide into any number of equal parts for the arch stones required—which in this example is seven—and draw the joints; the square holding *a b*, *b f*, *f l* may

be set out at will, but should be set out from the inside or concave face, so as to obtain a parallel arch joint.

The joint *c b′*, No. 2 C (Fig. 13), which is the arch joint cutting out to the vertical joint *b′*, illustrates this.

The moulds for working each arch block are a bed mould and two face moulds. These are already set out on plan (Fig. 9) and elevations (Figs. 10 and 11), except the addition of a square line to the extreme size.

To work the springer:

For the bed mould take *A c*, *B d* from the plan (Fig. 9) and transfer to 1 C (Fig. 12); the dotted line B B′ is line of the soffit on the bottom bed, the line *c c′* is the line of joint on top bed, the line *d d′* is the line of arris of the arch joint in soffit, and the line A A′ is the radiating vertical joint. No. 1 A (Fig. 12) is the face mould for convex face, and No. 1 B, Fig. 12, is the face mould for concave face; both of these are transferred from 1 A and 1 B (Figs. 10 and 11), with the addition of the square line *e e′*.

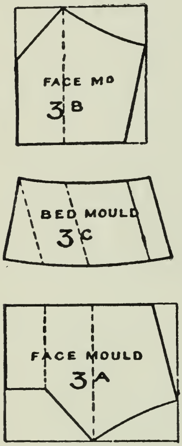


FIG. 14

Work the two beds (bottom and top) parallel to each other, and of the height of the face mould. Scribe the bed mould No. 1 C (Fig. 12), on both beds, and work the two faces convex and concave through, and also the vertical joint A *a*, which must be at right angles to beds; this will form a portion of a hollow cylinder similar to sketch, Fig. 7. Now scribe in the face moulds 1 A and 1 B (Fig. 12), on the convex and concave faces respectively, and work the arch joint *c d* through, and for the soffit, cut in arrises to the lines, and work drafts parallel to the bed B B′ until the whole of the soffit is finished.

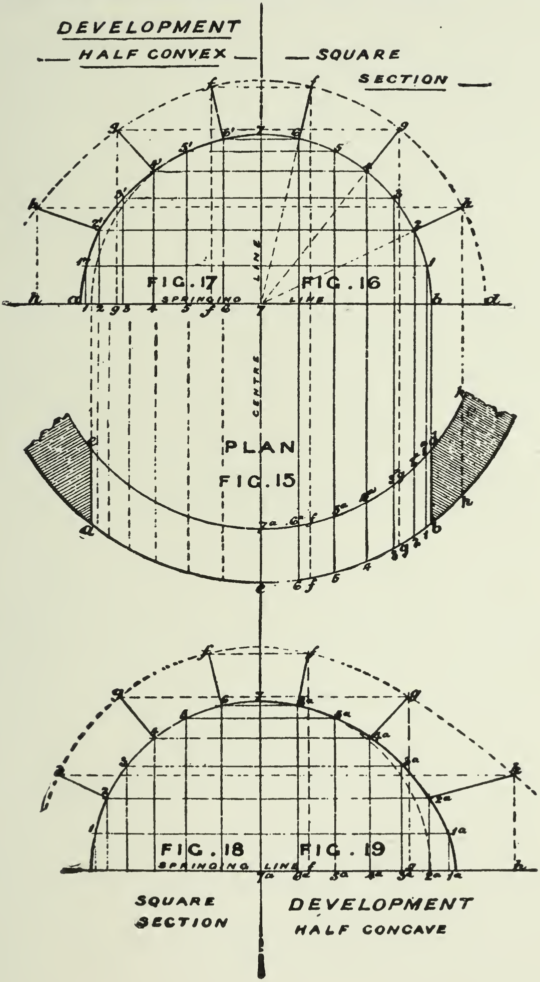
In this arch the soffit is not a winding surface.

To work the Second Arch Stone No 2 A (Fig. 10).

Let No. 2 C (Fig. 13) be the bed mould, project the extreme points *b h*, No. 2 A (Fig. 10), on to springing line A C. This being a developed face, it will require folding back on to the segment line A C E of plan (Fig 9), as *b d h*, and transfer this to No. 2 C, which gives the bed mould.

No. 2 A (Fig. 13) is the face mould for convex face, and No.

ARCHES *CIRCULAR ON PLAN*



2 B (Fig. 13) is the face mould for concave face, and both of these are transferred from 2 A and 2 B (Figs. 10 and 11), with the addition of the square line *l*.

Work the two beds (bottom and top) parallel to each other, and to the height of the face mould. The bottom bed is worked as a surface of operation for the application of the bed mould, and it is all cut away except the arris *d d'*. Scribe the bed mould 2 C (Fig. 13) in on each bed, and work the two faces convex and concave through, and scribe in the face moulds 2 A and 2 B (Fig. 13).

Work the vertical joint *b b* square with either the top or bottom beds, and work the bed *b c* and joint *c d;* then joint *g h*, and, lastly, soffit *d h*.

Fig. 14.—Nos. 3 A, 3 B, and 3 C are the face moulds and bed mould of the third arch stone, and together with the keystone are projected and worked in precisely the same manner as the foregoing Nos. 1 and 2 stones.

It will be advisable for the student to work small models, which should be constructed to scale in plaster, clay, or other soft material. The moulds for these models may be cut out of stout drawing paper, and in their application will be found the best method of obtaining knowledge of these subjects.

SKEW ARCH AND NICHES

To construct a Semi-circular Arch Rib, the oblique angle of which does not extend more than ten or twelve degrees from a right angle, the joints being parallel to axis, and in the same planes.

This is not a difficult problem, as the arch within these limits may be set out and worked as a right arch; but beyond these a different principle of construction is necessary.

Fig. 1.—Shows the elevation of the arch, which is a semicircle.

Fig. 2.—Shows the plan of the arch, B G and D J being the opening, B D and G J the inclination or angle of skew, E and F the centers, A and H the outer face line of the arch, and C K the inner face line of the arch.

There is no difference in the outer and inner faces of the arch, both being alike, but the terms are here used for purpose of explanation.

Project A C, B D and G J, H K from the plan to the springing line (Fig. 1), as *a c*, *b d* and *g j*, *h k*, with *e* as center, and *e a* and *e b* as radius, describe the semi-circles *a o h* and *b m g*, for the outside face, and with *f* as center, and the same radius, describe the semi-circles *c p k* and *d n j*, for the inside face. For the joints, divide the arch into any convenient number of equal parts—in this example seven—as *q r s t u v* on line *b m g* of intrados, and with the same divisions repeat on the line *d n j*

SKEW ARCH

— ELEVATION —

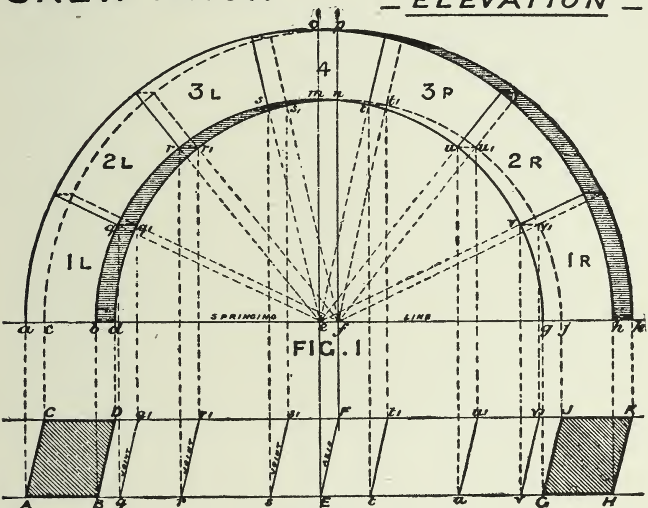


FIG. 2

— PLAN —

as *q′ r′ s′ t′ u′ v′;* from the center *e* draw radiating lines through these points, and produce to the outside curve or extrados for the outside, and for the inside of the arch; repeat the same from the center *f*. It will be observed that the direction of joints is perfectly horizontal, the lines *q q′*, *r r′*, *s s′*, etc., being level; the radiating lines and joints are also parallel to each other, and are therefore in the same place.

This is all the setting out required, with the exception of the joint moulds.

To work the Arch Stones.

Fig. 3.—Let No. 1 L be the face mould of the springer and A and B the joint moulds.

The face mould 1 L is transferred from the elevation Fig. 1, and the bottom bed or joint mould A, from plan (Fig. 2); for the joint mould B, draw a line parallel to joint *e′ f′*, and project *e′ f′* and *g′ h′* as *e f* and *g h*, of an equal and parallel thickness, as X X at A and B.

Work *a′ b′ e′ f′* outside face of springer No. 1 L, to a plane surface, and *c d g h* inside, face parallel to it; scribe the face mould into extreme size on each face as *a′ d′ e′ g′ h′;* scribe in the segment line *f′ b′*, giving arris of soffit on outside face (this may be done by drawing the mould back, as *h′ d′* is the same segment and also the same length as *f′ b′*)

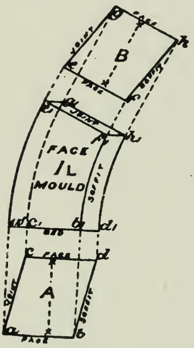


Fig. 3.

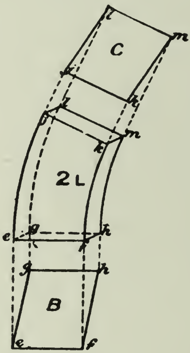


Fig. 4.

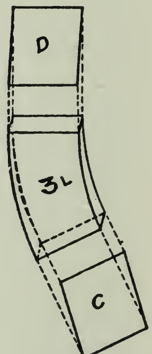


Fig. 5.

Work the bottom bed A, which is horizontal, and square with the vertical face, and scribe in the bed mould as *a b c d*, which will coincide with the lines on the face mould; now work the top joint B; this from the outside face will be full of the square, or, in other words, it makes an obtuse angle with the vertical face. This, however, is given by the face mould, as *e′ f′* is line of joint on the outside, and *g′ h′* on the inside.

Scribe in the joint mould B as *e f g h*, and work the soffit *b′ d′ f′ h′* through, as in a right arch, and finish with the back joint *a′ c′ e′ g′*.

Fig. 4.—No. 2 L is worked similar to No. 1 L; the top joint

mould B of No. 1 is the bottom joint mould of No. 2, and the top joint mould C of No. 2 is the bottom joint mould of No. 3, and so on—this is self-evident. The bevels of these joints are found by projecting the points of the face mould, as *j k l m*, etc., as before described.

Begin by working the two vertical faces *e f j k* and *g h l m* parallel to each other, scribe in the face mould No. 2 to the extreme size, as *e f h j l m*, and work both joints B and C; the top joint C is full of the square, whilst the bottom joint B is slack of the square from the outside face, the amount of the obtuse and acute angle being given on the face mould.

Fig. 5.—No. 3 L and the keystone are worked precisely similar to the foregoing.

One set of moulds for one-half of the arch only is required, as the four face moulds and the four joint moulds will work the complete arch; being a plain arch without mouldings, the stones are reversible; this is apparent on looking at the elevation, but should there be an architrave moulding on one face, a mould to each stone is then required.

To construct a Spherical Niche in a straight wall with horizontal splay beds, and with vertical joints.

Figs. 6 and 7.—Show the elevation and plan of the niche.

Let A E be the face line of the niche on plan (Fig. 7), B D the opening and C the center; with C B or C D as radius, and C as center, describe a semi-circle B K D, which is plan of extreme size of inside of niche; project A B C D E to the springing line on elevation (Fig. 6), as *a b c d e*, and at *c* erect perpendicular for the center line. With *c* as center and *c b* or *c d* as radius, describe the semi-circle *b k d* for the outer curve, and divide this into five equal parts as at *f g h i;* from *c* draw radiating lines through these points of division, cutting the horizontal bed at *l m n o*, giving the joints, the bevel of which will be continued horizontally round the niche as at *f i* and *g h*. For joints to the plan draw ordinates at *f g h i* and *l m*, etc., and project them on to line A E on plan (Fig. 7), as F G H I and L M, etc.; at L F M G describe the semi-circles, giving the horizontal line of splay joints. For dividing joints on the plan, take the second course first and divide the line of semi-circle F Q I into four equal parts as P Q R, and from C draw radiating lines through these divisions, producing them on to the line L N O, which gives the joints. The springers 1 L and 1 R in the first course

will require to be about half the depth of others in the same course, in order to break the bond (as will be seen by reference to the plan); therefore, on the line B K D, set off, say, little more than half for the two springers as B S and D V, dividing the remainder into three equal parts as at S T U V, and draw the lines through, radiating from the center to the back, giving the joints in the bottom course.

NICHE — ELEVATION —

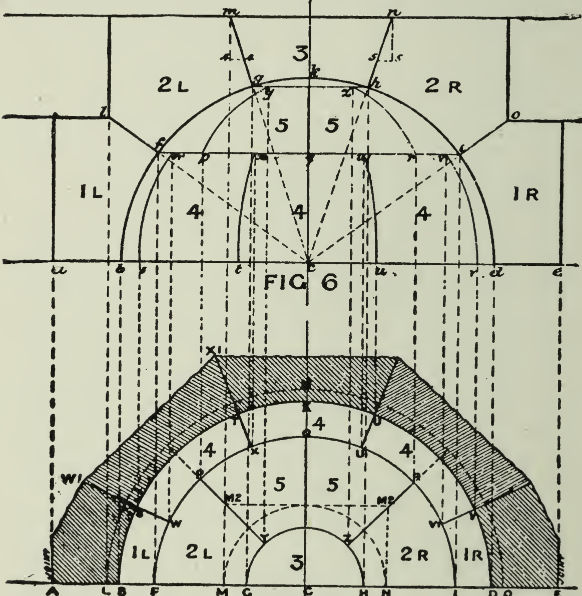


FIG .7
— PLAN —

The top course No. 3 is in one stone, and to prevent any tendency to slip out of its place forward, the upper part of bed may be kept square; this would require notching on the inside, as M M 2 and N M 2 on the plan, and *m* 4 4 and *m* 5 5 on the elevation.

The vertical joints are shown on the elevation by projecting up from the plan, as shown by the dotted lines *w p x q*, etc.

To work the Springer.

FIG. 8.—1 A is the bed mould transferred from the plan (Fig. 7), the line A F being the vertical face on the front, F W the horizontal line of arris of soffit and splay joint on the top bed, L O the outside line of splay joint on top bed, the dotted line B S the line of soffit on bottom bed, W W′ the line of vertical radiating joint, and A A′ the line of vertical face joint.

1 L is the face mould transferred from the elevation (Fig. 6), which will also apply as joint mould at W W′.

The form of the stone required to work this will be a wedge-shape prism, containing the bed mould to the extreme size on the top bed as A F W W′; the bottom bed is a little smaller, and is contained within the lines A B S W′, and of the extreme height of the face mould from *a* to *a′*.

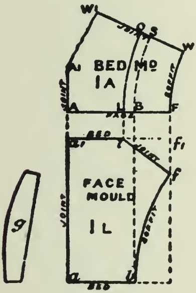


Fig. 8.

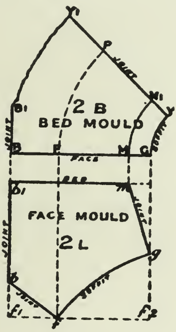


Fig. 9.

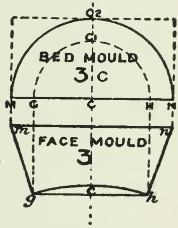


Fig. 10.

Begin by working the front vertical face A B F, and scribe the face mould 1 L on, as *a b f l a′*. Work the vertical joint A A′ as *a a′* square with the front face, and bottom and top beds square with the front face, scribing on the bed mould 1 A, and also the inside vertical joint W W′, scribing in the face mould as *a b f l a′*. It is necessary to work the whole of the top bed, although a portion from *l* to *f* 1 will be cut away for the splay joint, in order to get horizontal line F W at *f*; to obtain this arris, square down the concave line from F to W to the depth at *f*, or a draft from F to W may be worked by the aid of a template. This being done, trammel the line *f* parallel to *f* 1, giving the arris line required; the line L O is marked on the

top bed with the template, and the splay joint from *f* to *l* then worked off. The soffit now remains to be worked; cut in the drafts B S on the bottom bed and F W on the top bed, and drafts *b f* on the face and joint; a convex template is used as at *g* for the intermediate drafts, which are cut in as close as convenient, until the whole surface is worked.

The template *g* must not be applied parallel to the joints, but to lines radiating from the center.

The three No. 4 stones will be worked similarly to the foregoing; one vertical joint is worked first as a surface of operation, instead of the front face as in the springer.

To work No. 2 *L Stone.*

Fig. 9.—2 B is the bed mould transferred from the plan (Fig. 7), the line B G being the vertical face on the front, and G Y the horizontal line of the arris of soffit and the splay joint on the top bed, M M′ the outside line of the splay joint top bed, the dotted line F P the line of soffit on bottom bed, Y Y′ the line of vertical radiating joint, and B B′ the line of vertical face joint.

2 L is the face mould, transferred from the elevation (Fig. 6), which will also apply as joint mould at Y Y′.

The form of stone required to work this will be a wedge-shape prism, containing the bed mould, to the extreme size as B G Y Y 1, and of the extreme height of the face mould, from *f* 1 to *b* 1.

Begin by working the front vertical face, and scribe the face mould 2 L on as *b* 1 *b f g m*. Work the vertical joint *b b′* square with the front face, also the top bed, and scribe the bed mould on. Work the bottom bed as a surface of operation; the only part required being the arris of the splay joint, and soffit F P, the rest of the bed being cut away.

This is the easiest and most accurate way of working, but the bed need not necessarily be worked as a whole, a portion only being required, sufficient to obtain the arris line F P; in this case the soffit F G should be worked after the arris line is drawn on the bed, by a convex template made from *f* to *g*, and the splay joint is worked from a beveled template made from *g f b*.

The remaining portion of the stone is worked as before described to springer.

The two No. 5 stones are worked similarly.

To work the Keystone No. 3.

Fig. 10.—3 C is the bed mould transferred from the plan (Fig. 7), the line M N being the vertical face on the front, M C 2 N the top line of the splay joint, and G C 1 H the line of arris of soffit, and the splay joint on bottom.

No. 3 is the face mould transferred from the elevation (Fig. 6),

NICHE —ELEVATION—

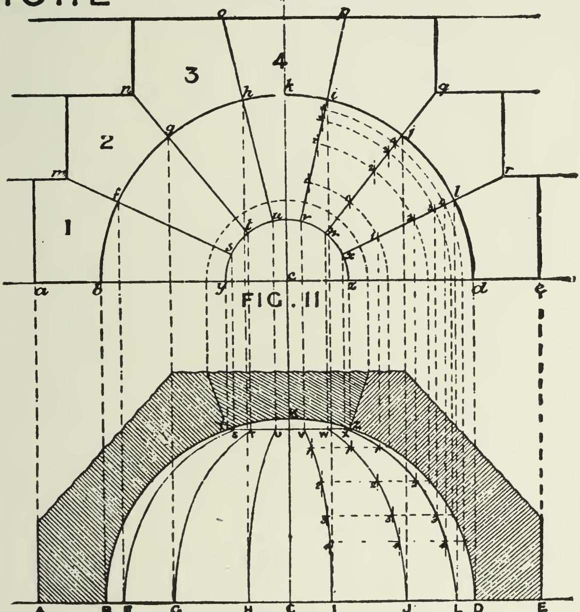


FIG. 12.
—PLAN—

Begin by working the vertical face M N, scribing in the face mould as *g h m n*. Work the top bed through square with the face, scribing in the bed mould, also the bottom bed parallel to the top at extreme points *g* and *h*, and with a template scribe G C H the arris of the soffit and the splay joint. Work the joint round tc the splay lines, then the soffit by cutting in the draft *g c h* on the front, and with a convex template made from C to C1, complete the surface.

The niche need not be jointed as here shown, for much depends on its size, and the size of the stone convenient to use, but the general principle of working will be the same.

To construct a Spherical Niche in a straight wall, with joints radiating from the center.

Figs. 11 and 12.—Show elevation and plan of the niche.

Let A E be the vertical face line of the niche on the plan (Fig. 12), B D the opening, and C the center. With C B or C D as a radius, and C as a center, describe the semi-circle B K D, which is the plan of extreme size of the inside of niche, and project A B C D E to the springing line *a e* on the elevation (Fig. 11),

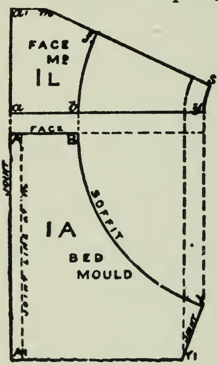


Fig. 13.

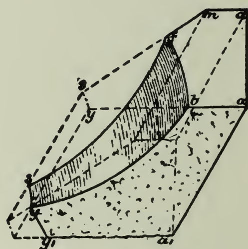


Fig. 14.

as *a b c d e*. At *c* erect a perpendicular for the center line, and, with *c* as center and *c b* or *c d* as radius, describe the semi-circle *b k d* for the outer curve. With *c y* as a radius and *c* as the center, describe a semi-circle for the center stone, which may be of any convenient size. Divide the semi-circle *b k d* into seven equal parts as *f g h i j l*, and through these points of division from *c* draw radiating lines cutting horizontal beds at *m n o p*, etc., and the center stone at *s t u v*, etc., which gives the joints. Draw ordinates from *f g h i*, etc., and project on to the line A B as F G H I, etc., and repeat the same at *s t u v*, etc., on the line Y Z, giving joint lines on the plan; to determine points in the curve of the soffit for templates, the dotted lines at the right hand of the niche show how they

are obtained. The dotted segment line from 1 to 1, 2 to 2, 3 to 3, etc., on elevation will be the section of curve at corresponding points on the plan at 1 1, 2 2, 3 3, etc., and also gives the points in the line of curve for the joints on plan, although the last named is not necessary for the setting out or the working.

To work the Springer 1 *L.*

Fig. 13.—1 A is the bed or joint mould transferred from the plan (Fig. 12), the line A B being the front vertical face, B Y the line of soffit, Y Y 1 the splay joint, and A A 1 the vertical face joint.

No. 1 L is the face mould transferred from the elevation (Fig. 11).

The form of stone required will be that of a wedge-shape prism (as in sketch, Fig. 14), containing the face mould to the extreme size as *a′ a y s m*.

Begin by working the bed or joint *a b y*, keeping the segmental line B Y fair for arris, and scribe the bed mould 1 A on. Work the vertical face and scribe in the face mould 1 L, and the other bed *m f s*, scribing in the bed mould 1 A. Work the vertical joint *a a′*, and top bed *a′ m*, and, lastly, the soffit, the working of this being guided by one or two templates made from 1 1, 2 2, etc.

The remaining stones are worked similar to the foregoing, keeping in mind the principle that the stone is contained within the wedge-shape prism, thus making it easy of comprehension.

The following are cases that require special treatment: Soft soils of a great depth; soft soils with hard strata beneath; soils not having a uniform resistance, formed of rocks which have hollows or fissures filled up with some softer material.

Foundations in the first case may be made in one of two ways, or by a combination of both—by sheet piling; by forming the foundation on planks.

Sheet Piling. Sheet piling, as shown in Figures 1 and 2, is used to prevent the lateral escape of the soft soil; it consists of flat timbers, about 9 in. to 11 in. × 3 in., driven in and enclosing the site to be built upon, the area of the latter being sufficient to withstand the pressure brought to bear upon it; as the soil cannot escape, it must necessarily remain and support the structure. If the site is to be drained it must be done before the building is erected.

In order to enclose a site with sheet piling, it is necessary to drive guide piles into the soil, at intervals of from 6 feet to 10 feet apart. These usually consist of timbers 9 inches square and upwards, pointed and shod with iron at the lower extremities, as shown in Figure 3. The point consists of a pyramidal block of cast iron, about 6 inches in length, and having a base about 4 inches to 5 inches square; this has four mortices, about 2 in. × ½ in. by about ¾ in. in depth. This is placed on the end of the pile, which has been cut as a truncated pyramid, the iron block completing the latter, and is fixed with four straps of wrought iron about 1 foot 6

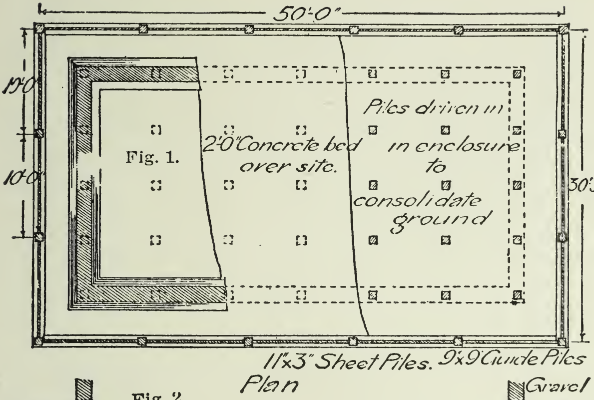


Fig. 1.

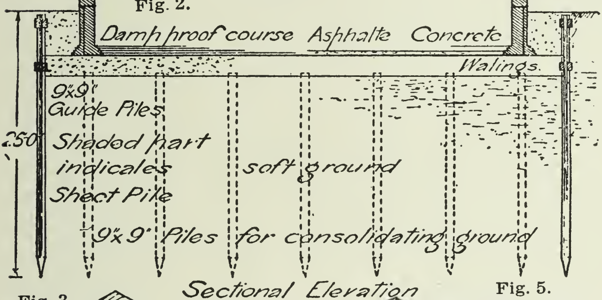


Fig. 2.

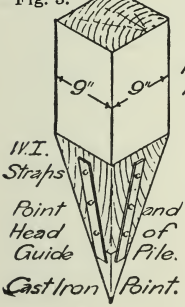


Fig. 3.

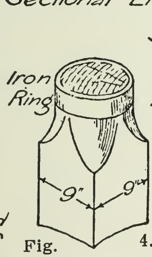


Fig. 4.

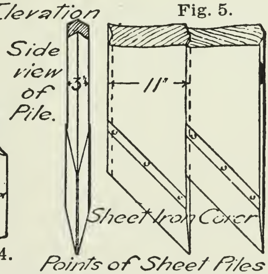


Fig. 5.

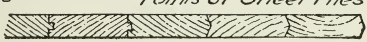


Fig. 6.

inches in length, with the ends turned to fit in the mortices of the cast-iron points. The straps are fixed to the wood pile with large clout nails, the point being thus fixed, as shown in Figure 3. The guide piles are driven in to within about 2 feet of the ground; they are connected together by horizontal timbers about 9 in. × 6 in., bolted to them in pairs, with a space between equal to the thickness of the sheet piles. Two pairs of waling pieces are thus fixed, one at the ground level, and the other near the top of the piles in the spaces; between these the sheet piles are driven, the walings serving to keep them in an upright position. The joints of the sheet piles are prepared in three general ways: square, grooved and tongued, or bird's-mouthed together, the first and last being those most commonly used, the second and third being shown in Figure 6. The sheeting piles are pointed at their lower ends, in the way shown in Figure 5, to cause them to draw in one direction; they have a piece of sheet iron nailed over the end to protect the point.

The ground within the enclosure is frequently consolidated by driving in piles as shown in Figures 1 and 2, the tops of these being covered by a layer of concrete covering the whole site within the enclosed area.

Plank Foundations. These are useful in soft and very wet soils. Each may consist of a platform of timber formed by two layers of planking, as shown in Figure 7, the lower-most layer being placed at right angles to the length of the wall; the uppermost parallel to the length of the wall and being spiked to the first, on this the brickwork or masonry footings are commenced. The best and most plentiful wood for this purpose is elm, which if kept constantly wet is practically imperish-

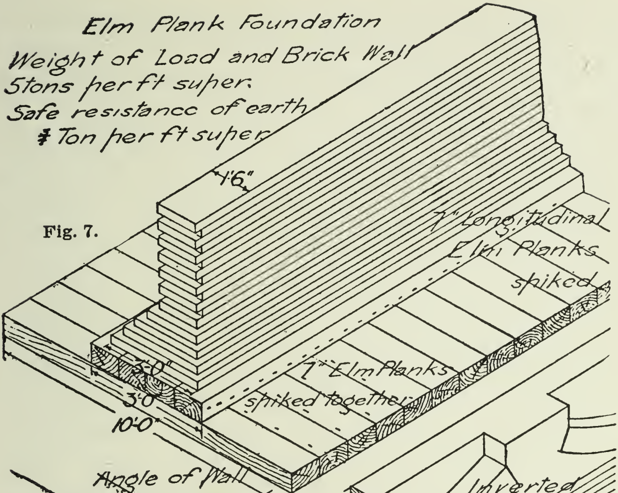

Elm Plank Foundation
Weight of Load and Brick Wall
5tons per ft super.
Safe resistancc of earth
Ton per ft super.
1'6"
1" Longitudinal
Elm Planks
spiked
5'0"
3'0"
10'0"
1" Elm Planks
spiked together

Fig. 7.

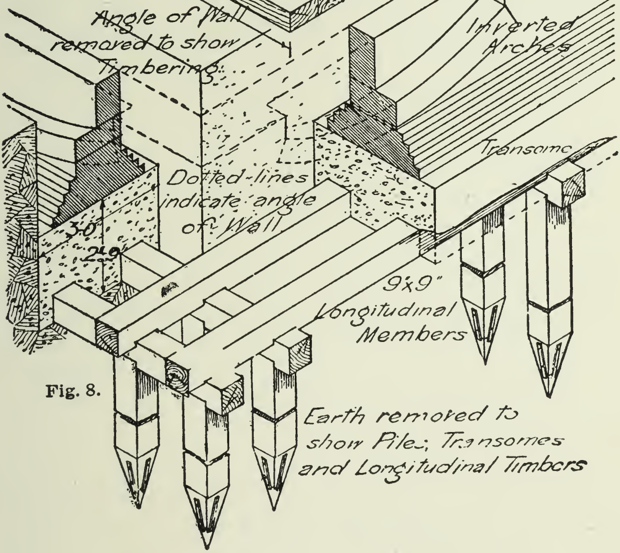

Angle of Wall
removed to show
Timbering.
Inverted
Arches
Transome
Dotted-lines
indicate angle
of Wall
3'0"
2'9"
9"x9"
Longitudinal
Members
Earth removed to
show Piles; Transomes
and Longitudinal Timbers

Fig. 8.

able, but where exposed to alternations of wetness and dryness will rapidly decay. Timbers for this purpose should be treated to one of the preservative processes, notably creosoting.

Example: Let it be required to support a wall 2 bricks in thickness and stressed with a load of 5 tons per superficial foot by a plank foundation, the safe resistance of the soil being ¾ ton per superficial foot. De-

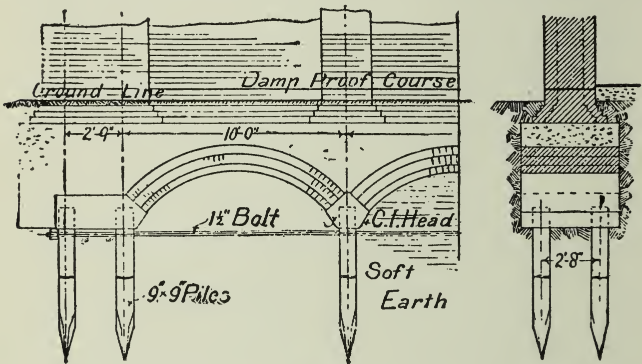


Fig. 9.

termine width of foundation and thickness of planking. required. Taking a length of 1 foot—

$$\text{width of foundation} = \frac{\text{total load}}{\text{safe resistance of earth}}$$

$$= \frac{5 \times 1\frac{1}{2}}{\frac{3}{4}}$$

$$= 10 \text{ feet.}$$

The length of the transverse planks forming the foundation are first laid; then longitudinal planks, in this case say to a width of 3 feet 9 inches, are laid on and securely spiked to the transverse. Upon this the foot-

ings, commencing with a width of 3 feet, are bedded. Treating the projecting planking as cantilevers, the lengths of which may be taken as 44 inches, the thickness may be determined.

Soft Soils with Hard Strata beneath. Cases of this description are commonly met with where buildings are erected on the banks of rivers; they are usually dealt with in one of two ways—by piling, until the pile refuses to be driven ¼ of an inch at each blow. Figure 9 illustrates piles driven in soft ground, supporting cast-iron heads, brick relieving arches upholding concrete beam, forming the foundation. By sinking piers down to the firm stratum.

Piling. The foundations are formed by driving piles from 19 inches square and upwards, similar to the guide piles mentioned, till their points rest on the solid ground. These are driven in in varying distances apart under all the piers of the building, which should be connected by inverted arches, as shown in Figure 8, to distribute the pressure uniformly along the foundation, and the piles being bridged both transversely and longitudinally by horizontal timbers of about the same sectional area as the piles, the whole being arranged as shown in Figure 8, which also illustrates the arrangement of the piles at the angle of a building. On the top of the timbering may be placed a platform of timber or a layer of concrete, on which the walls are built.

Pile Driving. Piles are driven in the ground usually by means of a ram, which is a block of iron, sometimes called a monkey, weighing from 200 to 700 pounds, raised by a crab winch, actuated by manual or steam power. Figure 10 is an illustration of a pile engine, capable of being worked by manual or by steam power.

The monkey in these machines is raised to a given height, when, by an arrangement known as a slip-hook, it is released, and descends with a force increasing directly as the height to which it had been raised. This

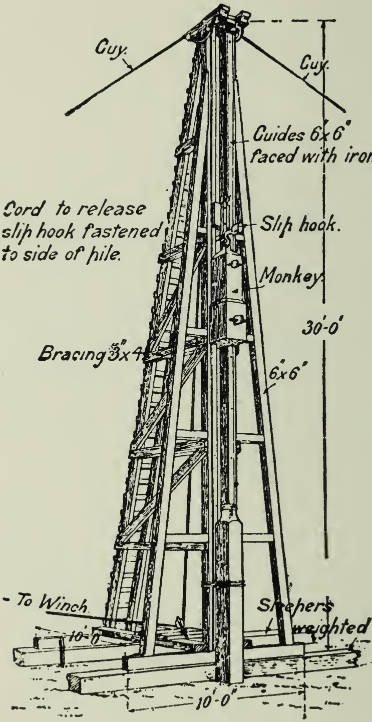


Fig. 10.

distance ranges from 5 to 10 feet, usually 5 feet, as a comparatively heavy monkey with a shorter fall is found practically to be better than a light monkey with a great fall, the latter having the tendency to shiver the pile

instead of forcing it downwards. Piles are considered to be sufficiently driven when the last blow does not sink the head more than ¼ inch.

The supporting power of a pile depends—upon the resistance at the point to resist penetration; the friction of the earth upon the sides of the pile; and if projecting above the ground, its strength as a pillar.

Small steam hammers are sometimes used as pile-driving machines.

Rankine says that it appears from practical examples that the limits of the safe loads on piles are as follows:

In piles driven till they reach the firm ground, 1,000 lbs. per square inch of area of head.

In piles standing in soft ground, by friction, 200 lbs. per square inch of area of head.

Sinking Piers. Piers of concrete or brick may be taken at intervals through the soft soil down to the hard sub-stratum; these are connected by arches or girders, upon which the superstructure is raised. If the soil is sufficiently firm, timbered excavations are made, and concrete or brick piers may be formed; but if the soil is waterlogged, or in any way insecure, brick cylinders may be sunk or iron cylinders or caissons, these two cylinders being filled up with concrete and forming solid piers.

Concrete Piers. The following example will illustrate concrete piers. Let a bed of soft soil 30 feet in depth overlie a compact gravel substratum, with a safe resistance of 8 tons per superficial foot. It is required to erect a wall with a load of 8 tons per lineal foot. Let the distance between the centers of adjacent piers be 15 feet, then the total load supported by each pier equals $15 \times 8 = 120$ tons. Let the weight of concrete pier be taken as 40 tons, then the total load on bearing stratum equals

Fig. 11.

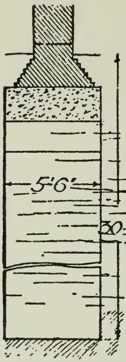


Fig. 12.

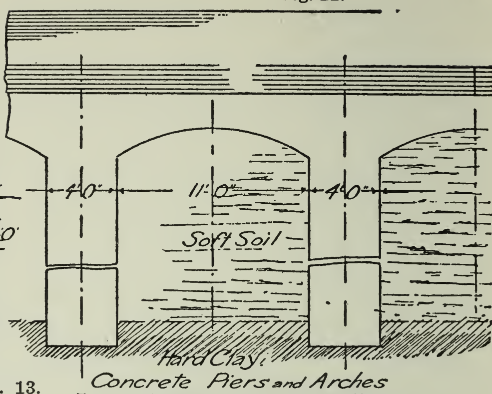
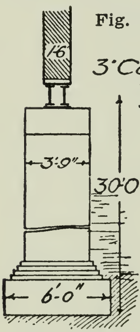


Fig. 13.



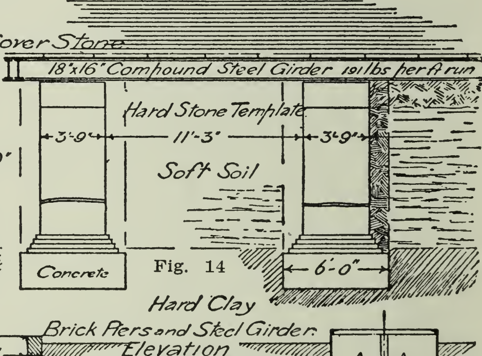


Fig. 14

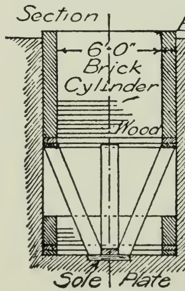


Fig. 15.

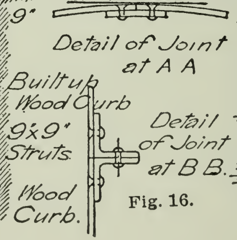


Fig. 16.

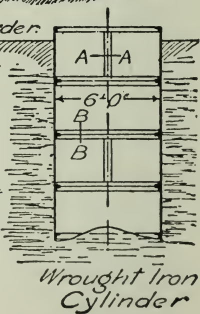


Fig. 17.

$120 + 40 = 160$ tons. The section area of concrete pier at base equals $160 \div 8 = 20$ superficial feet. Let the horizontal dimensions of pier to suit brickwork be taken as 5 ft. 6 in. $\times$ 4 ft., a timbered excavation having these internal dimensions is prepared, and then filled solid with concrete, the timbering being removed as the concrete is deposited, or, if the ground is uncertain, the timbering is frequently left in. Figures 11 and 12 show the above case.

Brick Piers and Steel Girders. Let a wall stressed with a load of 8 tons per lineal foot be carried by steel girders supported on brick piers in cement, the center lines of which are 15 feet apart. Let the safe resistance of brickwork in cement be taken as 10 tons per superficial foot, cement concrete, 1 of Portland cement to 6 parts of ballast as 15 tons per superficial foot, and hard clay as 4 tons per superficial foot.

The area of pier = total load on pier $\div$ safe resistance of brickwork, then—

$$\text{Area of pier at top course} = \frac{15 \times 8}{10} = 12 \text{ sup. ft.}$$

Let weight of pier be taken as 20 tons—

Area of pier at bottom course =

$$\frac{\text{total load on footings}}{\text{safe resistance of footings.}} =$$

$$\frac{120 + 20}{10} = 14 \text{ sup. ft.}$$

The resistance of this cement concrete being greater than the brickwork, it is unnecessary to calculate the

footings. Let the weight of the concrete be taken as 5 tons—

$$\text{Area of concrete} = \frac{\text{total load on earth}}{\text{self resistance of earth}} =$$

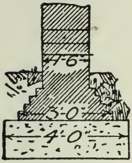
$$\frac{140 + 5}{4} = 36.25 \text{ feet.}$$

Let the dimensions of the horizontal section of the concrete be taken as 6 feet by 6 feet, and that of the brick pier as 3 ft. 9 in. $\times$ 3 ft. 9 in.

The clear span between piers will now equal 11 feet 3 inches, and the total distributed load will equal 90 tons; then from a manufacturer's list a 16 in. $\times$ 18 in. compound steel girder 191 lbs. per foot run will carry safely a distributed load of 96 tons over an 11 feet 3 inch span. Figures 13 and 14 illustrate this example.

Sinking Shafts. Brick shafts are sunk in one of two ways—First, by the method known as underpinning. In this a circular hole is dug in the ground as deep as possible without causing the earth to fall, a circular built-up wood curb is then laid perfectly level at the bottom of the hole, on which the brickwork is raised to the top of the shaft, care being taken to pack the earth tightly behind the brickwork. When this part is completed, a hole is dug in the center of the shaft as deep as possible, usually from 6 to 8 feet, a wood sole plate is bedded, inclined struts are then inserted, with one end resting on the plate, the other supporting the curb. At the completion of the fixing of these the earth is taken from beneath the curb at all parts to the level of the sole plate. A new curb is now inserted, and the brickwork built up to the underside of the old curb, and the struts removed. This process is repeated till the required depth is obtained, as shown in Figure 15.

Fig. 18.



Section

Fig. 19.

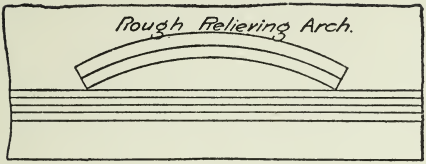
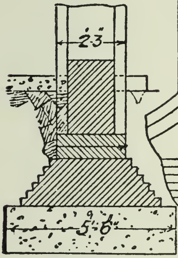
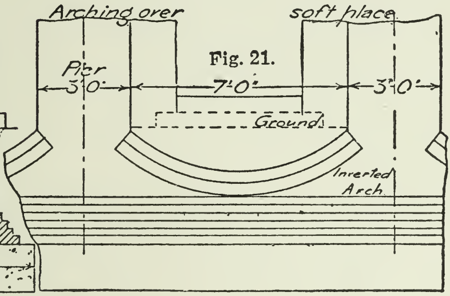


Fig. 20.



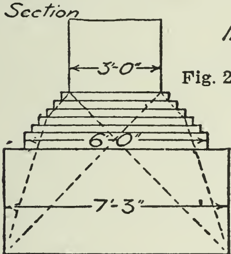
Section

Fig. 21.



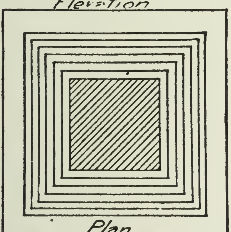
Inverted Arches.

Fig. 22.



Elevation

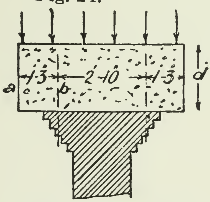
Fig. 23.



Plan.

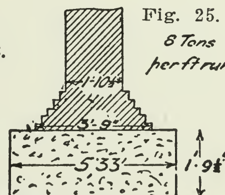
Empirical Rule for determining depth of Concrete

Fig. 24.



Pier Inverted.

Fig. 25.



Depth of Concrete determined by Calculation

Second method: A wood curb similar to the one in the last method, or an iron curb with a sharp edge, is employed here. The curb is laid on the ground, and the brick or stonework raised upon it. The earth inside the curb is removed, and on being taken from beneath, the curb with the brickwork sinks, fresh courses of the latter being added as the sinking proceeds. It sometimes happens that the friction on the sides of the brick lining is so great as to prevent the same from sinking; where this occurs, a second curb is placed inside the first, and a smaller shaft proceeded with in a manner similar to the first.

Iron Cylinder or Caisson. This is sunk similarly to the brick shaft just described, fresh plates being added as the earth is removed. These being in one mass, as shown in Figures 16 and 17, there is less likelihood of their going out of the vertical; there is not so much friction on their sides, they therefore sink easier than the above, and are better where there is much water in the soil.

If the above-mentioned shafts have been sunk to the firm strata, they are usually filled with concrete, thus forming a number of solid pillars. These are connected by arches or girders, and upon these the superstructure is raised.

Where soft places such as underground brooks traverse the tracks of walls it is usual to lay the concrete and bed the footings in the usual manner, and subsequently to build a rough relieving arch through the thickness of the wall over the soft parts as shown in Figures 18 and 19.

Soils not having a Uniform Resistance. Soils of this description, where the ground consists of rock or firm

ground in some parts, and in others of a soft soil, require careful treatment to prevent unequal settlement. The best method under these conditions is to cover the whole site with a bed of concrete, this being further strengthened by embedding steel rails into the concrete, spanning the soft parts; in this way a solid, hard platform is obtained over the whole site.

Soft soils subjected to Unequal Pressures. Where the pressures of a building are concentrated at piers placed at intervals in the lengths of the walls there is a danger of unequal settlements and fractures in the unloaded portions of the walls; to counteract this tendency inverted arches, as shown in Figures 20 and 21, are constructed between the piers, distributing the pressures uniformly over the whole lengths of the foundations.

Benching. Where buildings are erected on the side of a hill, and it is not practicable nor economical to excavate the whole site of the building to one level, the ground should be benched—that is, cut into a number of horizontal steps; on these the foundations are laid and the walls raised. The wall, if of brick, should be carried up in cement to the highest level of the foundation, and in large blocks of stone, if in masonry, in order to reduce the inequality of settlement due to the varying number of bed joints.

Subsoil Drainage. In low-lying districts, and in damp soils generally, the site for any building should be drained thoroughly before the structure is commenced, especially if there is the remotest possibility of any future cuttings being made, such as would be required for sewers or railways, which, by acting as a drainage system, would cause the failure of the foundations. Dampness in the soil has a deleterious effect upon the

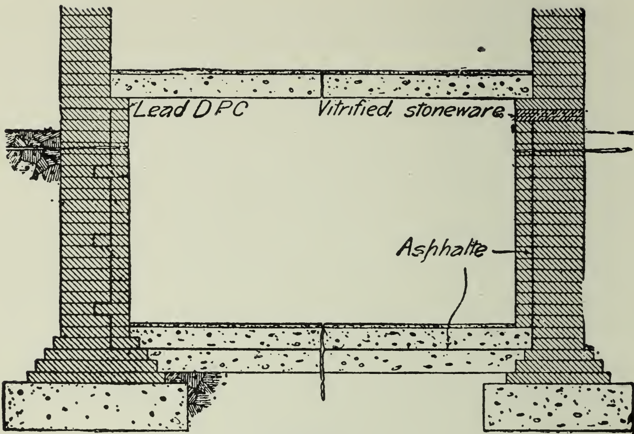

Lead D.P.C
Vitrified stoneware
Ashphalte

Fig. 26.

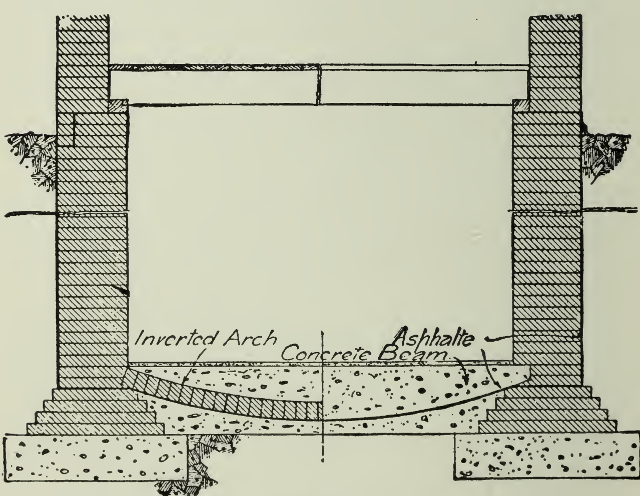

Inverted Arch
Concrete Beam
Ashphalte

Fig. 27.

health of the inmates, and also causes defects in the building: first, by the expansion and contraction of the earth, consequent upon the absorption and evaporation of moisture, which tends to rend the walls; secondly the damp is drawn up the walls. This may be stopped by an efficient damp-proof course; but where a wood floor is built on the ground floor, the timbers will be liable to dry rot. This may to a certain extent be avoided by ventilating the timbers; but even under these conditions the timbers invariably rot by being subjected to alternations of dampness and dryness. To reduce the possibility of this defect, a layer of concrete at least 6 inches thick should be spread over the whole area covered by the building, and a damp-proof course over the whole site, as shown in Figures 26 and 27.

Where isolated buildings have to be erected, the method of draining the land would be as follows: A trench or ditch is dug about the whole site to intercept any water that may flow over the land, and prevent it passing over the site. The site is divided into a number of parallel bays by narrower trenches than the above, all having a fall towards the lowest part of the site. Between these a number of still smaller trenches are cut, being arranged in a herring-bone pattern. These diverge from the center line of the bay in the direction of the fall, and discharge into the above-mentioned trenches; the latter empty themselves into the enclosing ditch, from which the water is conveyed by a continuation of the latter, or a pipe, to the nearest stream, if the land is nearly level; or if the ground is on the slope, the water is discharged over the same at a lower level.

Trenches. The depths of trenches usually vary from 2½ to 6 feet; they are cut as narrow as possible. The

bottoms of the trenches are cut to regular falls of not less than 1 in 100. The distance between the smallest trenches varies with the soil, being about 20 feet in clay to 40 feet in lighter soils.

A duct is formed at the bottom of the trenches for the conveyance of water. This may be done in one of three ways, as follows: by placing a layer of large stones at the bottom of the trenches, through the interstices of which the water can flow; a channel is formed with tiles, either flat or curved, or of thin slabs of stone (as shown

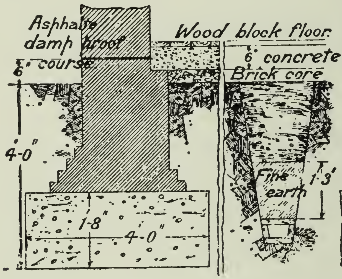


Fig. 28.

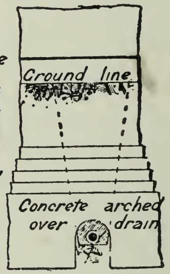


Fig. 29.

in Figure 28)—where a thinly stratified stone is abundant, a space is left between the joints of the pieces to allow the water to drain into the channel; agricultural drain pipes, as shown in Figure 29, are used, being made of earthenware, about 15 inches in length and about 2 inches diameter in the smallest drains, and from 3 to 4 inches in the main drains. The pipes are laid dry with a butt joint in the bottom of the trench; the ends are placed close together, the uneven surfaces leaving a sufficient space for the water to find its way through. Collars are sometimes placed over the joints to prevent dirt finding its way in, and to prevent the ends of the pipes getting

removed from each other while the trench is being filled. The collars consist of a piece of pipe of a larger diameter than the drain, into which the ends of the latter fit loosely.

Filling In. The space above stones, tiles, or pipes should be filled in with a fine porous earth to a depth of at least 15 inches, and above this the ordinary earth may be placed, the latter being shot in lightly at first, but finally well rammed.

Failure and Prevention. Such a drainage system is liable to failure from the following causes: by the accumulation of silt and vermin in the pipes; roots of trees, which push the pipes out of their place and extend up the pipe, and finally stop them up; where the pipes are under a building they are liable to fail by the settlement of the latter.

The first danger may be avoided by building a catchpit at intervals, which consists of a brick chamber, into which the pipe discharges; all the matter in suspension falls to the bottom of the chamber, the fluid flows off through the continuation of the pipe on the opposite side of the catchpit. To prevent vermin, such as mice, etc., from getting up the pipes, all the outlets should be covered by a wire guard or broken glass.

If laid near trees, collars should be employed, or socketed pipes set in cement.

If occurring under the walls of a building, a space should be left and arched above them, in order that the pressure may not be brought to bear on the pipes on the settlement of the building and consequent compression of the earth.

Widths and Depths of Concrete Foundations. For heavy buildings the widths of the concrete in the founda-

tion should be determined by the bearing strength of the ground on which they rest. The following table is useful in calculating the widths:

Table of Safe Loads in Tons, per superficial foot.	Tons.
Brickwork in mortar (sound stocks), grey chalk lime and sand, 1 to 2, six months old	$2\frac{1}{2}$
Lias lime and sand, 1 to 2, six months old	5
Brickwork in cement (hard stocks), Portland cement and sand, 1 to 1, three months old	10
Portland cement and sand, 1 to 1, three months old	8
Concrete—Portland cement and river ballast, 1 to 6, twelve months old	15 to 20
Lias lime and river ballast, 1 to 6, twelve months old	$2\frac{1}{2}$ to $4\frac{1}{2}$
Rubble masonry in lias lime	4

There are two methods of approximately determining the bearing resistance of the soil. By taking a square piece of wood of a given area, say, 1 foot, and loading it until the ground is impressed. By taking a bar of iron of given sectional area and dropping the same from a given height and noting the depth to which the bar sinks into the ground before it comes to rest, and then deducing from the laws of falling bodies the resistance that has been offered.

The maximum load is usually taken as $1\frac{1}{2}$ to 2 tons per superficial foot. Thus, if a brick wall built in lias lime mortar will safely carry 5 tons per superficial foot of section, and assuming the earth to be capable of supporting safely a uniform load of $1\frac{1}{2}$ tons per superficial foot, then the width of concrete should be $5 \div 1\frac{1}{2}$, or nearly 3.33 times the thickness of the wall. The depth

or thickness of the concrete is usually determined by experience, but as the most dangerous fracture that is likely to occur in concrete foundations is at the angle of about 45° to the base, causing the foundations to rupture in a number of triangular prisms or pyramids shearing or sliding upon each other, it would be better determined by drawing lines as in Figures 22 and 23, inclined 45° to the plane of the bottom of the wall above the footings from the thickness of the wall, and the depth required is shown by the intersection of these lines with the vertical lines, indicating the width of the concrete, supposing that the base of the foundations is on ground that is not likely to escape laterally under pressure.

The following illustrates the application of this theory to piers:

Example: Calculate the necessary dimensions of brick footings, and the width and depth of concrete for a square brick pier of 3 feet side, stressed to 5 tons per square foot of section, the safe loads of lias lime concrete, and earth being taken as 3 and 1 tons per superficial foot respectively.

The area of the base of the footings in feet will be the total load divided by the safe load per superficial foot of concrete. Let the weight of the brick footings be taken as approximately 1 ton, then—

$$\frac{\text{Total load}}{\text{Safe load upon concrete}} = \frac{45 + 1}{3} = 15\tfrac{1}{3} \text{ feet super.}$$

The side of base footings will therefore equal in nearest brick dimensions 4 feet 1½ inches; but it is usual to make the side of lowest course of footings twice the width of the pier, that is, in this case, 6 feet.

The area of the base of the concrete in feet will be the

total load divided by the safe load sustained per superficial foot by the earth. Let the weight of the concrete be taken as approximately 5 tons, then—

$$\frac{\text{Total load}}{\text{Safe load upon earth}} = \frac{45 + 1 + 5}{1} = 51 \text{ feet super.}$$

and the side of base of concrete will therefore equal 7.14 feet, say 7 feet 3 inches, as shown in Figures 22 and 23.

The footings being splayed at the usual angle, and the depth of concrete being determined by drawing lines at 45° from base of wall and the point of intersection with the calculated width of concrete, will give the depth, as previously explained. Figure 22 shows how the brick footings are usually arranged in practice, which, in this case, may be supposed to be substituted for the equivalent depth of concrete.

Depth of Concrete by Calculation. The depth of concrete may be obtained by calculating as for a cantilever under a distributed load.

Figure 24 shows the wall inverted to realize more clearly the pressure. The part between *b* and *c* may be considered as under compressional stress only, whilst the distances *a b*, *c e*, represent the lengths of the cantilevers.

Tall Piers. The height of a pier in brickwork above any horizontal section should not exceed twelve times the least dimension of that section. The area of the base of such piers should be proportioned to the pressure they have to resist. For economy in labor the sides of the piers are usually carried up vertically and have the same sectional area at top as at the bottom, that is, they have an excess of strength and therefore of material. For perfect and economical construction the horizontal sections of a pier at any part should be proportioned to the

Fig. 31.

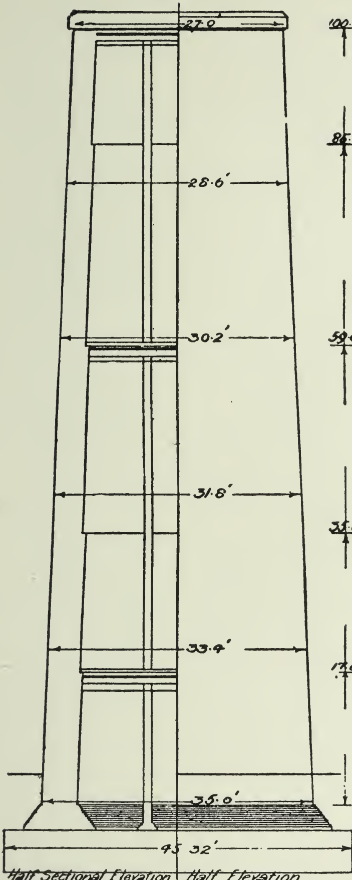
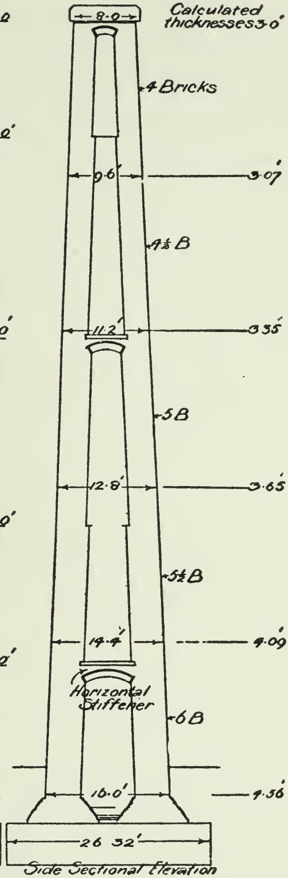


Fig. 32.



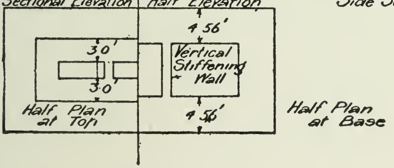


Fig. 30.

pressure upon them. It would only be in the cases of very tall piers supporting very heavy loads that it would be economical to design the piers to the theoretical sections, but if the piers are sufficiently large to build hollow then the theoretical section may be kept and built to with economy.

EXAMPLE I.: Let it be required to support a load of 50 tons at a height of 30 feet on a brick pier approximately square, the safe load on the brickwork being taken as 6 tons per superficial foot, and the weight of brickwork 112 lbs. per cubic foot.

$$\text{The area of the top course} = \frac{\text{total load}}{\text{safe load}}$$

$$= \frac{50}{6} = 8\tfrac{1}{3} \text{ tons per sup. foot.}$$

Figures 30, 31, and 32 show the construction of the pier with the necessary stiffening walls and arches.

Steel and Concrete Foundations. A common method of constructing foundations of walls and piers of buildings practised in America where the structure rests upon a yielding stratum, is to embed steel joists in concrete in order to extend the bearing surface. The methods of employing timber in foundations are defective unless it is known that the timber can be kept permanently wet or dry, as they quickly rot. Iron or steel rails embedded in concrete are not open to this objection, but where great weights are concentrated on points or lines, as under piers or walls, the rails are subject to deflection unless the concrete bed is very thick. I beams as now used are in every way superior to the above, as by employing a depth enough to reduce the deflection to a

Fig. 33.

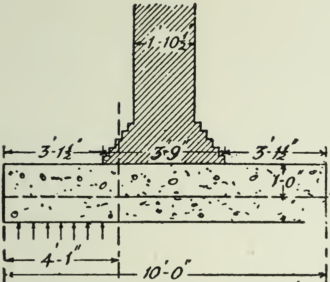
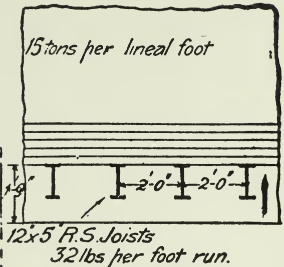


Fig. 34.



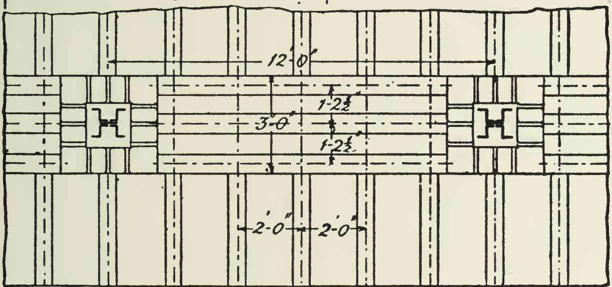


Fig. 35.

— Plan —

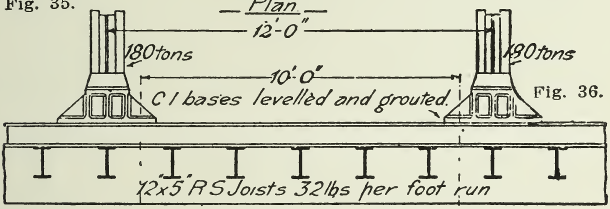
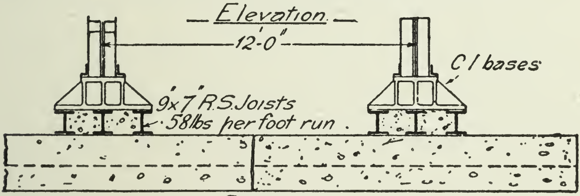


Fig. 36.

— Elevation —



— Section —

Fig. 37.

minimum, a comparatively thin bed of concrete only need be used, and a sufficient saving be effected in excavation and concrete to compensate for the employment of the steel beams.

This method of constructing foundations is especially suitable where the structure is erected upon a comparatively thin hard stratum overlying a soft and yielding stratum, and where consequently it would be unwise to damage the upper crust.

To prepare foundations in this manner it is usual to lay a bed of concrete of from 4 to 12 inches in thickness, and on this to place the beams at right angles to the wall at centres varying from 9 inches to 24 inches, as shown in Figure 34.

Example: A wall 1 foot 10½ inches in thickness supports a load of 15 tons per lineal foot. The width of footings at base to comply with bye-laws is 3 feet 9 inches. The safe bearing strength of earth is 1½ tons per superficial foot; therefore

$$\text{the width of foundation} = \frac{\text{total load}}{\text{safe resistance of earth}}$$

$$= \frac{15}{1\frac{1}{2}} = 10 \text{ feet.}$$

Grillage Foundations. In the case of piers, steel joists are placed in two systems crossing each other. This arrangement is termed a grilled foundation. The space between the joists is then filled in with concrete, care being taken to work the same well in between the flanges.

Figures 35 to 37 show the method of constructing a

Sections of Footings and Walls

Fig. 38.

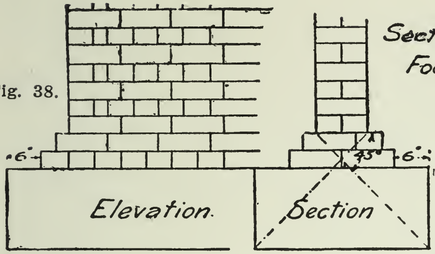
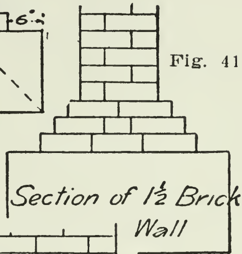


Fig. 39.

Fig. 41.



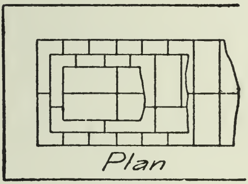


Fig. 40.

Fig. 43.

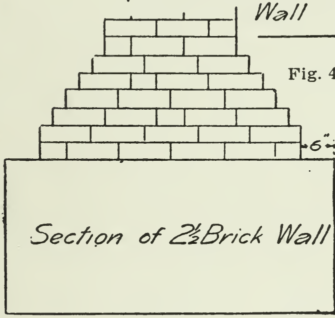


Fig. 42.

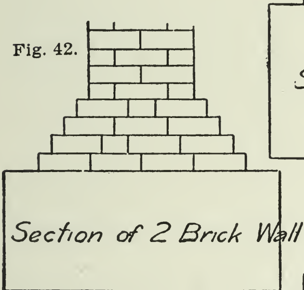
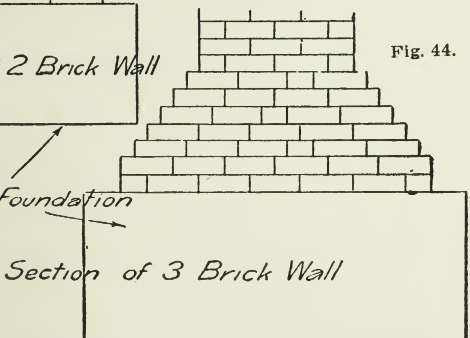
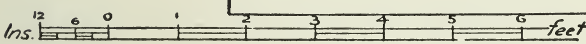


Fig. 44.

Concrete Foundation





grilled foundation, the weight of the building being supposed to be transmitted to the ground through piers.

Footings. These are the wide courses placed at the base of a wall to distribute the pressure over a greater area of ground. The course coming immediately upon the concrete is required to be twice the required width of the wall; thus, in a two-brick wall this course would be four bricks wide. Offsets of 2¼ inches are then made on each side of each successive course till the desired thickness is obtained. Walls of two or more bricks in thickness frequently have their bottom courses of footings doubled, as shown in Figures 43 and 44.

Care should be taken that the bricks in footings should be laid as far as possible as headers, but if stretchers are required in any course they should be laid near the center of the wall.

Figures 38 to 44 give sections of footings and walls in English bond from one to three bricks in thickness. Trenches in practice are excavated for beds of concrete from 9 inches and upwards in depth, and 12 inches wider than base of footings (6 inches on each side).

Seddon recommends that brick footings be dispensed with, and a deep bed of good cement concrete substituted for the footings and concrete foundation; where ballast is found on the site this is often a more economical practice.

Name of Earth.	Weight	
	Decimals of a Ton. Cubic Foot.	Tons. Cubic Yard.
Basalt, solid	0·083	2·25
Bath stone, solid	0·052	1·40
Chalk, damp to wet, loose to close ...	0·056 to 0·074	1·50 to 2·00
Clay	0·054 to 0·059	1 45 to 1·60
Flint, solid	0·074	2·00
Granite	0·078	2·10
Gravel and shingle	0·046 to 0·055	1·25 to 1·50
Limestone (lias to compact mountain)	0·067 to 0·078	1·81 to 2·10
Marl	0·044 to 0·052	1·20 to 1·40
Mud, at surface	0·044	1·20
Mud, at about 15 feet in depth ...	0·048	1·30
Peat, hard, and top mould	0·036	0·98
Portland stone, solid	0·065	1·75
Quartz, solid	0·076	2·05
Sand, dry river	0·041	1·10
Sand, damp and shaken	0·055	1·50
Sandstone, solid	0·063 to 0·072	1·70 to 1·95
Shale	0·074	2·00
Slate, solid	0·080	2·15
Trap, solid	0·078	2·10

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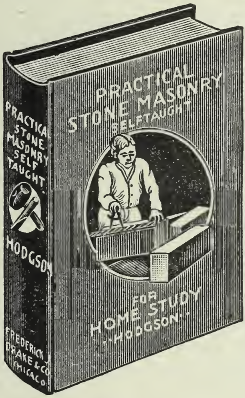
Practical Stonemasonry Self-Taught

FOR HOME STUDY

BY FRED T. HODGSON



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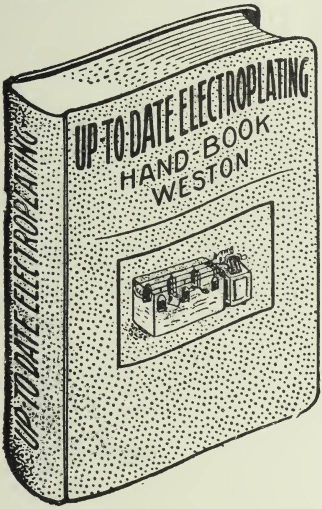

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